DISCOVERY

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Inspecting a glass record at the G.P.O. Research Station

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DISCOVERY

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The Progress of Science

Industrial Research in Britain

BRITISH industry spent about £30 million on research (including development) in the financial year 1945–6. The work was done by about 10,000 qualified scientists and 35,000 other workers. Owing to man-power shortages there has not been much expansion since 1945–6, and the figures given will be substantially true for the present time.

These are some of the main points emerging from a report on *Scientific and Technical Research in British Industry*, a statistical survey by the Industrial Research Secretariat of the Federation of British Industries. The report is packed with valuable data, though its potential value is reduced because the statistics have not been collected or analysed scientifically. The data are analysed by numbers or percentages of firms which undertake this or that activity. But as the output of one firm in an industry may be some hundreds of times that of another, such figures are almost meaningless. Thus to say that 25% of British chemical firms permit publication of most of the research done in their laboratories gives only a vague picture of the total amount of industrial chemical research that is published. A number of biases have been allowed to affect the analysed figures which could easily have been avoided by the use of sampling techniques familiar in social survey and market research work. These arise from the fact that for statistical purposes the various industries have been arranged in broad groups, but no precaution has been taken to ensure that the proportions of the various subdivisions in the sample for each group correspond to the actual proportions within the group as a whole; and no use has been made of the well-known techniques for correcting this bias. For example, a 'miscellaneous' group, in which half the firms surveyed belong to the scientific instrument industry, is clearly unrepresentative. Thus many of the statistics in the report can be taken as only a crude indication of the real position. But once that limitation is realised there are many useful facts to be learnt from it.

Actually the report is based on data from 420 firms, which are estimated to cover about 75% of the total industrial research effort, though less than 50% of the number of firms doing research. Only firms spending £1000 or more per annum on research are included (another bias, but less dangerous since it is explicitly stated). These 420 firms spent £21,815,000 on research in the year 1945–6, employing 35,634 workers on the job, of which 7894 were qualified scientists. By far the largest research expenditure was in aeronautical and automobile engineering where 28 firms spent £8,494,000; next comes the chemical industries with £5,166,000 from 65 firms. Chemists—3479 of them—formed the largest group of qualified scientists, engineers coming next with 2553.

At the beginning of 1946 when the survey was made, 61% of the firms were planning to expand their research activity before the end of 1947, though man-power and other shortages have seriously curtailed these plans. An overall expansion of 25% in qualified man-power was contemplated. The biggest increase of demand then envisaged by the firms surveyed was for chemists, with a rise of 839 or 24%. But the biggest relative change was to be a 65% increase in the number of biologists, from 257 to 424. This last might be one of the most significant changes from the point of view of the scientific profession itself. For it is well known that before the war some professors of biology used to discourage students from taking up the subject on the grounds that the prospects of employment were poor. The new opportunities for biologists were almost confined to the food and drink industry (38 more), and the chemical industry (122 more), where, no doubt, the chief cause is the appearance of penicillin and other microbiological products.

Plans for new laboratories call for an increase of 2,500,000 square feet of floor space. In a press statement accompanying the report the Secretariat say that building licences have been granted for about half the expansion but shortages are delaying completion. If capital cuts are to be made, they suggest that laboratory extensions should be exempt from pruning, since they involve only a small expenditure but promise large returns.

What general conclusions can be drawn from this report about our industrial research? The overall picture is encouraging. The £30 million a year amounts to about

two-thirds of one per cent of the annual value of our industrial products, and at this figure research expenditure begins to approach the sum which experts have for years estimated to represent the essential minimum of research. This £30 million represents approximately a ten-fold increase in industrial research in the last fifteen years. Man-power, not money, is the limiting factor at present; it will be no use asking industry to spend more on research until more man-power is provided—and the only way in which that can be done quickly is to reduce the disproportionate expenditure on defence research on which we remarked in our October 'Progress of Science'.

The statistics also reveal some of the main weaknesses in our research effort. The balance of research between different industries does not always correspond to real needs. The 52 metallurgical firms covered by the survey spent only £936,000 on research. These include on equal terms both the non-ferrous industries, many of which are technically advanced and spend freely on research, and iron and steel, which is one of our most backward industries and presumably bears the minor share of that £936,000. The aircraft and motor industries are important, but it is difficult to believe that they merit a research expenditure nine times as great as that of the basic metallurgical industries and a research man-power eight times as great.

It has often been said that the weakest link in British applied science lies in the poor liaison between fundamental research and industrial research. The report confirms that this remains true. Only 19% of the firms surveyed maintained close contacts with universities and technical colleges, 44% had limited contacts, and 37% no contact or quite negligible contacts.

As a whole the position revealed in the report might be summarised in the words: very encouraging progress since pre-war days, but many weaknesses remaining which will have to be eliminated by a more integrated approach to the problem of industrial research.

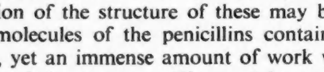
Colouration and Edibility of Birds

In 1890 the late Sir Edward Poulton published his classic work *Colours in Animals*. Exactly fifty years later another great study of the subject appeared—*Adaptive Coloration of Animals*, in which Dr. Hugh B. Cott elaborated the great mass of work which had been stimulated by Poulton's pioneer studies. In this book Cott undertook an exhaustive examination of the relationship between colour patterns and self-preservation. During the war, while Dr. Cott was working as a camouflage officer in the Army, he found the opportunity to make experiments to test the relationship between colour and edibility in birds. The greater part of this experimental work was done in Egypt using hornets (*Vespa orientalis*). In each experiment the insects were presented with either a choice between the flesh of two species of birds or, in the control experiments, of the same species. The number of insects feeding at each carcase was counted at regular intervals. The experiments involved 38 species of birds which were examined from the point of view of (*a*) the palatability of their flesh to the hornets and (*b*) their relative conspicuousness in the field. As a general rule the more conspicuous the bird, the less palatable was its flesh to hornets. Thus Dr. Cott grouped the species as follows: (i) Inconspicuous and palatable, 18 species; (ii) conspicuous and unpalatable, 14; (iii) inconspicuous and unpalatable, 2; (iv) conspicuous and palatable, 4. These experiments are described in detail in Dr. Cott's paper published in the *Proceedings of the Zoological Society*, 1947, Vol. 116, pp. 371–524. Generally comparable results were obtained in experiments in which the edibility of the flesh was assessed from the readiness with which cats and men ate it.

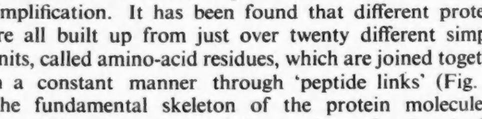
Synthetic Proteins

The proteins are undoubtedly the most fascinating and important group of compounds which occur in living matter, being almost unrivalled for size and complexity of structure and versatility of use and function. After forty years of research, the general idea of their structure is beginning to be understood. Many of them exist as conjugated proteins, in which a non-protein group is united to a true protein portion, as for example, in haemoglobin, the respiratory pigment of the blood, in which the protein globin is joined to haem, a complex iron-containing compound. The non-protein portion is usually relatively small in size and simpler in structure, and the difficulties arise when investigating the nature of the true protein portion, for this may contain tens or hundreds of thousands of atoms joined together in a unique fashion which gives the protein its identity.

The majority of the substances with which the organic chemist is commonly concerned have, at the most, only a few hundred atoms in their molecules, and even the determination of the structure of these may be far from easy; the molecules of the penicillins contain less than fifty atoms, yet an immense amount of work was needed to elucidate their structure. The protein molecule may present an almost insoluble problem but there is a fortunate simplification. It has been found that different proteins are all built up from just over twenty different simpler units, called amino-acid residues, which are joined together in a constant manner through 'peptide links' (Fig. 1). The fundamental skeleton of the protein molecule is essentially a long chain of these units, a few hundred to many thousands in number, and the relative frequency of



(i) *Amino-acid residues* have this general structure, where R is a variable group giving twenty or more different sorts of these units which are joined in long chains, as in (ii) to build up proteins.



(ii) The peptide-link is —CO—NH—

Fig. 1.

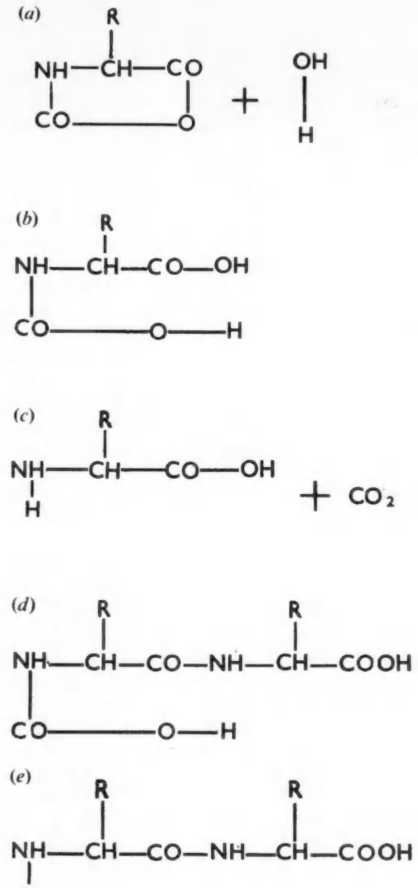
(*a*)

(*b*)

(*c*)

(*d*)

(*e*)



(*a*) A molecule of *carboxyamino-acid anhydride* is attacked by a molecule of water, and the ring opened:

(*b*) This is the unstable *carboxyamino* acid, which loses carbon dioxide (CO_2).

(*c*) An *amino-acid* is formed. The left-hand end can act as water does in (*a*) and attack another of the anhydride rings.

(*d*) This is unstable and loses carbon dioxide as in (*c*).

(*e*) A chain of two residues has now been formed. The left-hand end now behaves exactly as in (*c*) and (*d*), and the cycle is repeated until thousands of residues have joined together.

FIG. 2.—Protein Synthesis.

different units and their arrangement characterises each different protein. The possible number of different proteins is astronomical in magnitude, as, for example, a chain of a thousand units where each could be any one of, say, twenty different amino-acid residues, could be built up in $\frac{20^{1000}}{2}$ different ways—over a thirteen thousand figure number! Many workers in the field cherish the hope that there is some regularity in the sequence of different units, so that the presence of super-units would introduce a further simplification. There still remains the added complication that the long chain is only the framework of the molecule, and a chain may be extended, folded or coiled, cross-linked with itself or other chains, and so on.

The building-up of such a structure in the laboratory starting with simple synthetic materials is a great challenge to the ingenuity of the research worker. Emil Fischer, often considered the greatest organic chemist who has lived, succeeded in 1907 in joining together eighteen amino-acid residues into a chain, and his product showed a few protein-like properties in spite of its relatively small size. The labour involved was very great and experimental difficulties are likely to prevent his methods from being adapted to build up appreciably larger chains. In the following year, Leuchs and Geiger observed that some material they were working with 'went bad' (as the laboratory saying goes) when it was kept and formed an insoluble gum, but they failed to appreciate the real significance of this change. Little more was heard of it until this year when the American chemists Woodward and Schramm at Harvard realised what had happened and re-investigated the matter. They have shown that the final product is a polymer in which at least 10,000 amino-acid residues (of a type occurring in natural proteins) have joined together into a long chain through true peptide links, and the synthetic product is therefore analogous to the proteins. The polymerisation was carried out in benzene, and as the chain grew in length, the solution became more and more viscous, and finally after a fortnight, when it was poured out and left to dry, a clear tough film was left.

The starting material for the Americans' experiments was carboxyamino-acid anhydride, an amino-acid residue with a little bit extra, and with the two ends of the structure bent around and joined so as to form a ring. This cyclic molecule is relatively stable except in the presence of an 'activator', the simplest being water, which opens the ring up, joins on and gives an unstable material which loses carbon dioxide to yield an amino-acid, which can also serve as an 'activator', opening up a second ring and joining on, then the material so formed again losing carbon dioxide leaving two amino-acid residues joined together (Fig. 2). This again acts as an activator and opens up and joins on to a third ring, and so on, until a huge chain has been formed. This type of self-perpetuating mechanism is known as a chain reaction.

A long chain containing two different sorts of amino-acid residues has been obtained by using a mixture of the two corresponding starting materials. It remains to be seen how far it will be possible to form chains according to a given specification, and it is certain that the possibilities of doing this will be investigated exhaustively, and a new phase in the study of protein chemistry may well be inaugurated, as protein-like models would be very valuable tools in the development and testing of new techniques and hypotheses.

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The Proton Microscope

IN the quite near future it will probably be possible to see objects magnified a million times. There can be very few branches of science in which recent progress has been quite

so startling as in microscopy. Twenty years ago, with only the ordinary optical microscope available, the absolute theoretical limit of magnification was about 3000 times; in practice the magnifications achieved were only a fraction of that—of the order of one thousand times.

There would actually be little difficulty in designing a set of lenses which would magnify much more than 3000 times. But nothing at all would be gained—the image would be larger, but it would be correspondingly blurred, and no more detail would be revealed. It is the light, in fact, that sets the limit to the magnification—it is only possible to see a detail if it is large compared with the wavelength of the light being used.

It was in the 1930s that the next step was taken—the design of an electron microscope.

With techniques that are foreseeable at present, the limit of useful magnification by an electron microscope would seem to be about 100,000 diameters. In practice 10,000–40,000 diameters are attained.

The wavelength associated with a particle decreases as the mass increases (to be precise, at equal energies the wavelength is inversely proportional to the square root of the mass). Hence the possibility that a proton microscope would give magnifications even greater than those of the electron microscope. A million times magnification seems theoretically attainable. The practical development of the idea has till now been largely carried out by Claude Magnan and Paul Chanson of the Collège de France in Paris. They have completed a first model and are now at work on a second one which is intended to magnify 600,000 times. As usually happens, the greater magnification has to be paid for in the loss of some other advantage. In this case, the power of penetration of protons is so low that the microscope cannot be used to examine objects by transmission; reflection at a grazing angle has to be used instead.

REFERENCE

"Du microscope électronique au microscope protonique", by C. Magnan, *Atomes*, October, 1947, pp. 334–9.

Ray Lankester and Popular Science

Scientists frequently complain of the poor treatment which scientific matters receive in the press, but when doing so it would be well to remember how very recent are the first important attempts to bring science to the newspaper reader. Reporting of scientific events naturally goes back a very long way, and through a great part of the 19th century some of the best scientists wrote occasional newspaper articles. But the first really good scientist to make a regular job of writing for the daily press was born only 100 years ago. He was Sir Ray Lankester who was born in 1847 and died in 1929. His actual newspaper writing belongs to the early years of this century.

Lankester's heredity and early environment was well adapted to the creation of a populariser of science. His father was not only a medical man, but a zoologist and a botanist, a friend of Dickens, and a man who supported himself by literary work and popular lecturing together with such practice as came his way. It was under the influence of such a father, who founded a science journal and in whose house Darwin and Huxley were regular guests, that Ray Lankester grew up. He went up to Cambridge, and then to Oxford where he came under Rolleston's tutorship for his zoological studies in what was then the new University Museum. Since Lankester *père* had been Secretary to the Royal Society it was meet that the son himself should become a Fellow by virtue of his excellent academic work, first as Oxford don, next in a London chair of zoology, and then in the Oxford chair of the same subject. Lankester returned later to London, to the British Museum and the Fullerton chair at the Royal Institution.

Though not to be classed as a genius, Lankester was a very good scientist, doing important work in evolutionary theory. But it is as a populariser of science that he will be remembered—for his articles in the *Daily Telegraph*, which were afterwards collected together in *Science from an Easy Chair*, *Great and Small Things* and *Diversions of a Naturalist*.

Lankester could write an interesting article on a subject which his fellow scientists would regard as stale—for example a quite gossipy description of a day's trip in Switzerland from Interlaken to the Eismeer and back, in which he discusses successively the mountain trout, the fertilisation of sage, the habits of edelweiss, contortions of strata in the valley walls, the Jungfrau railway, the scenery viewed therefrom, the objections of 'Alpine monopolists' to such railways as desecrations, mountain sickness, and the reactions to the scenery of 'a white-haired American lady' whom he met. Or at the other extreme, he could take hold of one of the vital scientific themes of the times, and present it to his readers in a way that revealed its full importance. That happens in his essay on 'The Supply of Pure Milk', where we can follow those first gropings towards our present knowledge of vitamins.

What were the elements in Lankester's success as a populariser? We can distinguish at least four. First the wide range of his scientific knowledge; he wrote little and with less success outside the biological field, but within biology he had a reasonable knowledge of almost everything. The wide range of his *extra*-scientific knowledge—he could write enthrallingly on dragons because he had at his fingertips not only the facts about the pterodactyl and the python, but also the details of heraldic dragons and a wide knowledge of the folk-lore of the subject. Third comes his consciously evolved technique of presentation. We can see something of this in his attack on 'Jargon of Science.' Here he listed three faults amongst writers and lecturers on science subjects when attempting to instruct 'the man in the street'. First, a pride or infatuation in using special terms of science, believing no other ones possible; second, a real lack among many learned men of his day to evaluate the abilities, the state of mind of would-be pupils, simply because imagination and sympathy were so often lacking; and third, the fault of trying to tell the audience or reader too much in a given time or space when a simple theme and not a host of complexities is required. Lankester could well afford to make such criticisms; for he practised what he preached.

And the fourth reason for Lankester's success was that he wrote with a purpose. In a general sense he felt strongly that the scientific education of the man-in-the-street was something very much worth doing. And beyond that, he used a large proportion of his articles for campaigning for very definite objects. He wrote vigorously against all

forms of obscurantism and superstition—against divination, spiritualism and palmistry ("These same lines . . . are present in the hands and the feet of the chimpanzee and other man-like apes, but no palmist ever read the ape's hand"). He severely criticised those people who tried to contaminate biology with vitalism. He poured scorn on theologians who tried to determine at what point in the evolution of the race or in the growth of the individual the soul is created, and led on to the conclusion "that the marvellous qualities and activities of living things and that inscrutable wonder, the mind of man, are outcomes of the orderly process of Nature no less than are the miracles which we call a buttercup, a rock crystal, a glacier, the noonday sun!" And he had certain social sermons to preach too—the whole point of the article on 'The Supply of Pure Milk' lies in its closing sentences: "It is imperative that good, nourishing milk, free from germs of tubercle and of diarrhoea, shall be accessible to the millions in this country who cannot afford to pay eightpence a quart for it. It is a difficult demand to meet. What is said above explains the difficulty, and suggests an attempt to overcome it."

At first sight modern newspaper writing on science compares unfavourably with that of Lankester. Certainly none of it reads so smoothly or so clearly. But the comparison would be false. Almost all Lankester's good writing is in the field of biology, a subject which had at that time hardly begun to approach the complexity and technicality that characterise practically the whole of science today. The modern popular writer has an immensely more difficult job of explanation and simplification to do. And what modern newspaper could spare the space for Lankester's leisurely style?

In point of fact we have today one important scientist, Haldane, who writes regular articles at a newspaper level as successfully as did Lankester—in spite of the fact that he tries to tackle the whole range of modern science. There are some other good scientists who make brave attempts, though they do not come into the same category as Lankester and Haldane as they contribute only occasional articles. And if some scientific correspondents, who are not active scientists, make a less good showing, perhaps that is because the profession of scientific correspondent is even younger than that of scientist-turned-populariser. That the scientific correspondents of Britain did not band together to form the Association of British Science Writers until this year is a measure of the newness of this profession.

James Hutton (1726–97)

THIS year is the hundred-and-fiftieth anniversary of the death of James Hutton, the author of the first important attempt to establish a scientific view of how natural forces operate in the geological history of the earth. If accurate observation and substantially correct theory (coupled with a modest allowance of errors) be taken as the test, he may be said to have succeeded; for his view of physical and dynamical geology is very close to that of today. But if we demand also that a scientist should convince others and so contribute directly to the stream of knowledge, then Hutton's work must be looked on as one of the great heroic failures of the history of science.

Hutton's geological views were first set out in two papers to the Royal Society of Edinburgh in 1785, and later expanded into his book, the *Theory of the Earth*, published in 1795. The view which he advocated seems so simple now that it is very difficult to realise how revolutionary it was when first propounded. The basic principle was that the geological history of the earth is to be explained in terms of the slow long-term operations of just those forces which are observed in action now—"the present is the key to the past", as he put it. In that framework he showed how rain, wind, mechanical erosion and chemical action wear down the land and carry the detritus into the sea, where new strata are formed; how these are consolidated by heat and pressure, and again uplifted to form new land; how granites, whinstones and porphyries are formed by the forcible intrusion of molten rocks between strata deep under the surface; how these molten injections alter and harden the rocks with which they come into contact. All these things he visualised as changing the face of the earth gradually and persistently over long periods of time.

When Hutton wrote, geology as a descriptive science, identifying the various strata and their relations, had made considerable advances. Within a few years after his death the introduction of palaeontological techniques brought this stratigraphical aspect of the subject to a stage recognisably similar to the modern. And already the descriptive side of geology was demonstrating its practical value to the miner, farmer and engineer. But on this foundation of descriptive fact and practical application the world of the later 18th century built a superstructure of fanciful theory. The main emphasis—and this not merely among theologians, but among most of the top-rank geologists—was on devising a theory of physical geology which would be consistent with the Mosaic revelation taken in its most naïve literal interpretation. To bring the world to its present state since its creation in 4004 B.C. meant introducing many catastrophic events—a universal ocean which originally covered the earth even above the highest mountains and which in its (not clearly explained) disappearance deposited the various strata where we find them; a re-appearance and further disappearance of this ocean, which was identified with the Deluge and was used to explain the later fossil-bearing rocks; and other cataclysms according to the taste of the writer.

A world that thought in these terms could not but be profoundly shocked at Hutton's statement that "the result of this physical enquiry is that we find no vestige of a beginning—no prospect of an end." Hutton was a profoundly religious man according to his own unorthodox lights, but to his contemporaries such statements as this seemed to be militant atheism. He was assailed from all sides—really on theological grounds, though the attacks were often camouflaged in a pseudo-scientific terminology. He gained a few disciples who fought for his theory even harder than he had done. But an overwhelming majority remained unconvinced and Hutton's influence on the actual course of further geological progress was almost negligible.

By a strange coincidence, the year of Hutton's death saw also the birth of the two men—Scrope and Lyell—who were to establish 30 years or so later the theory for which Hutton had striven in vain.

In the course of the celebrations in September to mark the Jubilee of the discovery of the electron Sir Clifford C. Paterson, who has been director of the G.E.C. Research Laboratories since 1919, delivered a popular lecture which was illustrated by experiments and demonstrations. This article is an edited version of that lecture.

The Electron Liberated

SIR CLIFFORD C. PATERSON, F.R.S.

In 1897 at the Royal Institution, London, Joseph J. Thomson opened a new chapter—a great chapter—in the history of scientific progress.

His genius had revealed to him the nature of electricity. His experiments demonstrated how electricity could be liberated under control, from the metals which ordinarily hide its identity. His deductions showed the amazing properties of the minute entity—the electron—which is to electricity in the mass what a grain of sand is to the whole sea-shore. Electricity has since been shown simply to consist of millions of millions of these electrons all identically the same.

This may seem to us today a normal and obvious conception. In 1897 it was greeted by scientists as a wild speculation whose author could hardly himself regard it seriously. Electricity made up of particles! No, it was certainly not heralded then as the great step in scientific progress which it has since proved to be.

Scientists had at that time three clues as to the nature of what they had been calling the electric fluid.

First, in lightning and its laboratory counterpart, the electric spark, the electricity appears to be shot explosively out of the charged parts by the action of an electrical congestion that the electrons can't hold in any longer.

Second, in the carbon arc, the electricity is first enticed out of two rods of carbon through which it is flowing by drawing one carbon away from the other. Heat results, which evaporates a cloud of carbon particles. These constitute a bridge across the gap left between the carbons. The electrons, in crossing this, expose themselves in the open.

Third, there is the discharge in vacuum first studied by Hawkesby about 1700. When most of the air is pumped away from inside a glass tube which has a metal electrode at each end, the electricity can leave the metal much more quietly than in the case of the lightning flash owing to the rarefied gas left in the tube. It passes down the tube, causing a faint reddish glow as it excites the particles of air still left in the tube (Fig. 1).

The lightning, the arc and the glow—three manifestations of electricity, so different from each other. What could be the nature of the thing which exhibited itself in these different ways? There were many speculations during many generations of scientific thinkers, but no verifications.

Great was the thrill to the engineer and also his incredulity when Thomson demonstrated to him that the familiar amperes—the electric fluid as it was then called—the 'juice' as it is known by the irreverent today—actually consisted of minute elements of electricity of which 6,290,000 million million per second go to one ampere; or in other words make up sufficient electricity for lighting one good street lamp.

The lightness of these electrical particles is the thing which also needs to be grasped. There are about as many of them in the weight of one gram as there are grams in the weight of the whole world, and 28 grams go to make up one ounce.

But to the engineer all this was but academic fancy. It had no special importance because unless things went wrong with his apparatus these electrons were all confined to his metal wires. The electrons were not free. No effective way had been put into his hands of making these electrons leave the peaceful paths of metallic conductors.

Forty Years of Electronic Engineering

It was only when it was shown to him what wonderful effects could be produced when this stream of electrons was made to leave those conductors, that the engineer set to work to develop and to use every kind of free electron agency and device. In Electrical Engineering this movement, which started about 40 years ago, has revolutionised many things in life, and has many more surprises in store.

The secret of the revolution is that a stream of free electrons, usually in a vacuum, can be manipulated with such ease that the electricity can be increased or decreased at a rate of millions of times per second or alternatively as slowly as is desired. It can be reversed or stopped equally quickly. It can be modulated automatically in the most complicated ways, and hardly a limit is set to the amount of electrical energy which can be so controlled. Finally, whilst the agency which imposes this control on the electron stream is usually itself electrical, it is possible, for instance, to make light from an ordinary lamp or magnetism or heat the controlling agencies.

In many, but not all, electron liberating devices, the tap which opens the passage and lets the stream of electrons out of the metal circuit is an incandescent part of it, heated

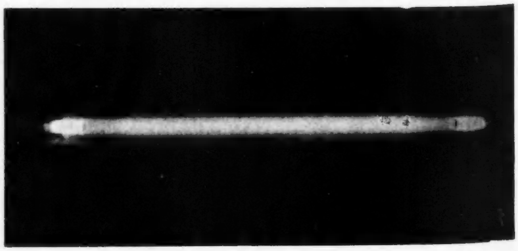


Fig. 1.—A low-pressure discharge in air.

so hot that electrons emerge freely. That is what the filament, or in other words the cathode, in a radio valve is.

Valves and Photo-electric Cells

When electricity passes through a hot filament, or other white-hot substance, it is like water which has hitherto been passing through a watertight lead pipe, coming to a length of worn-out porous hose. The water will soak through it, and if there is a good pressure will squirt out in a number of minute jets. Looking at it electrically, Fig. 2 illustrates the simple idea involved. The irregular black line represents any electric circuit and collection of electrical devices whatsoever. Such circuits usually consist of metal wire, and so long as this is cold the electrons are confined rigidly within it as they travel along the wire. But as the electrons pass through the red hot wire, A, they will be released from the interior of the wire and swarm around in a thin layer on the outside surface ready to be taken elsewhere the moment they are attracted away by externally applied electrical influences exerted from another metal electrode, B, nearby.

It is the instant during which the electrons are travelling from the hot solid through the short space—usually less than 2 inches—to the other electrode that the control is exerted which causes them to comply with the most exacting demands, flowing and ebbing, accelerating and varying with unthinkable speed and precision. They are controlled by the electrical dictates of the third electrode, C, as a complicated orchestra is controlled by its conductor.

The device in which this operation is carried out most perfectly is the well-known radio valve. It consists essentially of three electrodes—an inner hot component,

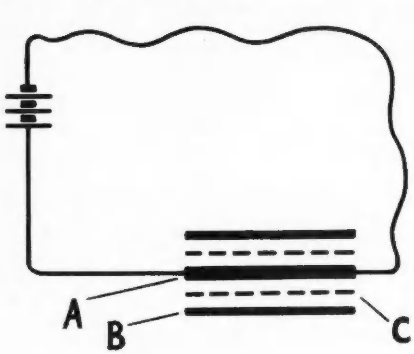


FIG. 2.—Electric circuit with hot electron-emitter.

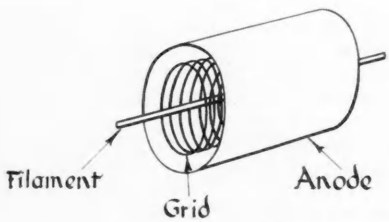


FIG. 3.—Valve electrodes.

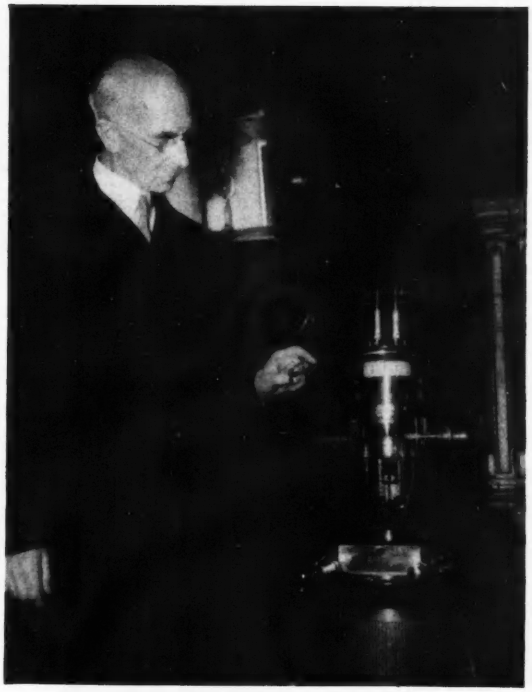


FIG. 4.—Sir Clifford Paterson demonstrates contrast in valve size.

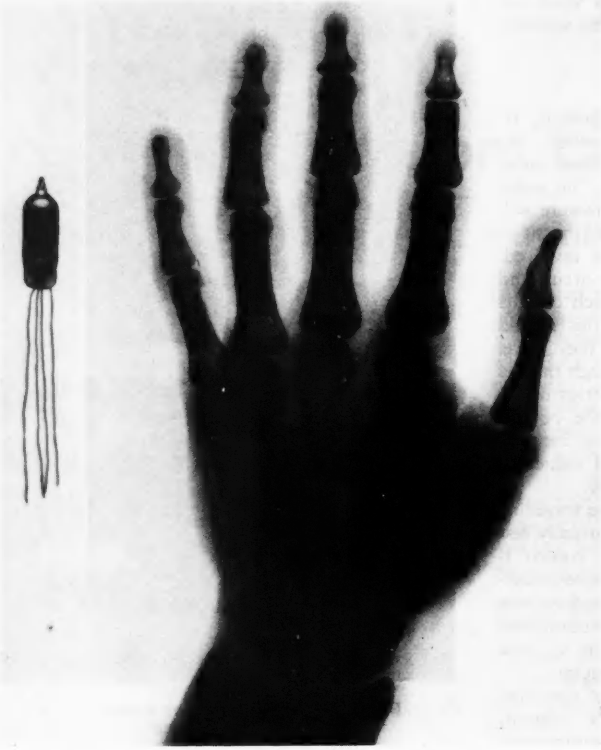
the *filament*, emits the electrons and the middle component, the *grid*, controls them (Fig. 3). The outer component, the *anode*, provides an electrical force sufficient to attract the liberated electrons away from the filament. The valve is so perfect for its purpose because the speed at which the electrons can be made to manœuvre is so high. They can be made to change, to reverse or to oscillate so rapidly that the complete stream of electrons will flow back and forth if necessary well in excess of three thousand million times per second.

Two examples of modern valves—the largest and not quite the smallest valves made are shown in Fig. 4. The largest, used for generating the powerful impulses which launch radio messages across oceans and continents, can handle about the same power as that of a locomotive used on suburban services. The smallest is for handling the reception of very weak pulses—all that is available of our powerful impulses by the time they reach the points where they have to be picked up—perhaps thousands of miles away.

An exterior view of these valves may be impressive, but it is not very informative. The internal system of electrodes of the smaller valve can be seen in the X-ray photograph (Fig. 5), in which a photograph of a human hand is included to indicate the size of the valve.

The X-ray photograph of the large valve (Fig. 6) shows the electrodes which are hidden inside the $\frac{3}{8}$-in. wall of its large copper envelope, and the same hand is reproduced beside it.

A second device for liberating electrons and rendering



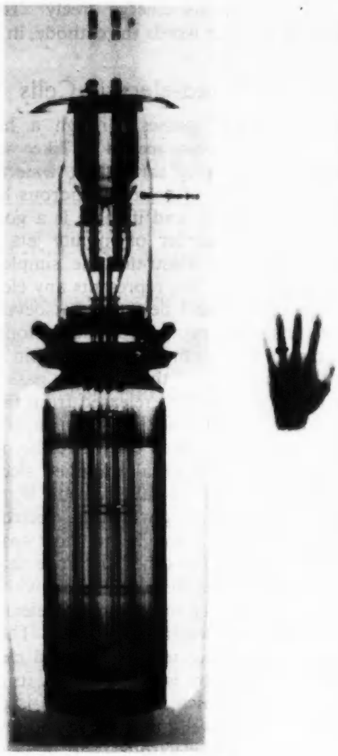


FIG. 5 (*left*).—X-ray photograph of the small radio seen in Fig. 4. FIG. 6 (*right*).—X-ray photograph of the large radio-broadcasting valve (type C.A.T. 14) seen in Fig. 4, showing internal electrodes photographed through its 8-in. diameter copper electrode. Size can be judged by comparison with the hand in each photograph.

them free of the materials in which they normally congregate, is the photo-electric cell (Fig. 10). It looks much like an ordinary wireless valve but it is entirely different in its function. For the electrons are liberated not from a hot filament, but from a specially sensitised cold surface which has the property of releasing electrons only when light falls on it. In Fig. 10 the cathode is the sensitive surface and the anode is the collector of the electrons which leave the cathode so long as light is falling on it. If the cell is in the dark no electrons leave the cathode for the anode. The cell is dead. But let in ever so little light and the electrons instantaneously begin to leave the sensitive cathode. The number of electrons so set free is very closely proportional to the strength of the light. If the light is doubled, the free electrons are also doubled.

The number of electrons which flows is extremely small, but that does not matter when we have at our command amplifying valves of the kind we first considered, which will magnify their number and their exact fluctuations to almost any extent, and with the highest precision.

These photocells are used to the fullest extent of their possibilities in the reproduction of talking films. They are also the key to television. In some of the latest television devices the photocell has to receive over three million impulses in every second. That is to say, light is turned on to the cell only for one three-millionth of a second, yet the cell must respond accurately to it and emit electrons and be ready immediately after to receive a new light impulse and emit a new flight of electrons. And so on three million times per second.

It may be asked why are these extremely rapid actions of the electrons wanted? What is the practical use of them? These two liberated-electron devices—the radio valve and the photocell—can be made to illustrate the wonderful way in which liberated electrons can be used and controlled in modern electrical engineering. They should give an impression of the power of the tool which the physicist has put into our hands.

So much of what we see and hear consists, if analysed, of extremely rapid happenings. The eye and the ear are quite unconscious of these high-speed fluctuations and vibrations, although sensitive to them. They transmit to the brain only the mass effect of them—just as the pistons of a motor-car engine are sensitive to the thousands of explosions per minute which make the engine rotate, but the driver sitting in the car is only conscious of the smooth running of the engine and the fact that the car is moving under his control. He does not appreciate the complicated train of events which goes to make up each individual explosion in a cylinder of the engine.

So, all unknown to us, the machinery of our eyes and ears is responding in detail to rapid and complicated

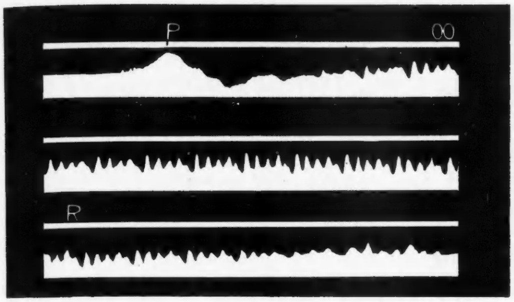


FIG. 7.—Wave form of the word "POOR".

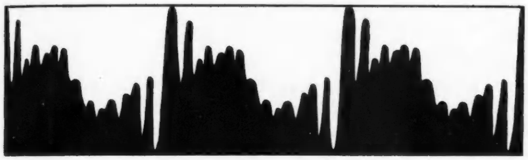


FIG. 8.—Wave form of clarinet note.

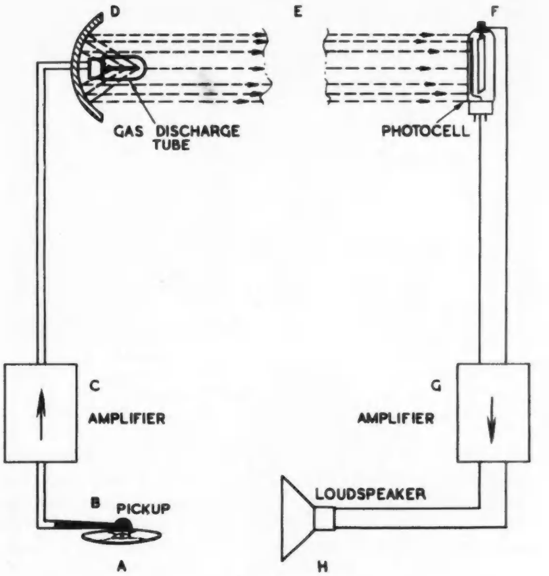


FIG. 9.

oscillations of which we have no conception apart from the investigations of science. The sound of our voices, of what does it consist? Of very complicated pulses carried by the air. What is such a pulse? It is a travelling disturbance of the pressure of the air made by the breath as it passes over the vocal organs and issues from one's mouth. The character of the sound heard depends upon the minute pressure variations which take place during the pulse. We can show those pressure changes in the same sort of way as the barometer chart shows the infinitely slower variations of atmospheric pressure by the use, for instance, of a cathode ray tube, yet another kind of free electron device.

The changes of pressure in the air are converted, by a microphone, into varying electrical voltages which are used to deflect the cathode ray tube trace. These pressure changes are, however, so rapid, that one cannot see in detail what they are like, unless they are 'frozen' by taking a photograph. A diagram of the word POOR, occupying about a fifth of a second, and prepared from such a photograph, is shown in Fig. 7. The initial strong pulse of the explosive consonant 'P', followed by the rapid high-frequency pulses of the rest of the word, can be seen clearly. Fig. 8 shows three single pulses of the wave-train given by the clarinet. The detailed form of this is what gives the clarinet its distinctive sound character.

If we want to reproduce, transmit to different places, or magnify such a train of air pulses, we must do so by manipulating electrons so that their electrical fluctuations accurately reproduce these high-speed effects. That is, we must make exact electrical copies of these sound pulses. When the pulse is powerful more electrons pass; when it quickly diminishes, the number of electrons diminishes in proportion. The art of doing this is the basis of the long-distance telephone, the talking picture, broadcasting transmission and reception, trans-oceanic telephony and a hundred other uses, less important perhaps at present, but growing in importance as our technique develops.

The apparatus depicted in Fig. 9 can be used to demonstrate the versatility of these two electron-liberating devices in the amplification, conversion and reproduction of sound.

The gramophone record 'A' has recorded on it (as mechanical impressions on vulcanite) the elaborate pulses such as we have just seen of music or speech. With its needle and electrical pick-up 'B' these impressions are converted into exactly equivalent electrical impulses. These impulses are faithful copies but very weak, so they must be amplified in the apparatus 'C'. In this there are radio valves in each of which in turn and with inconceivable speed, the free electrons are made to copy exactly in their own movements the impulses impressed on them. Each successive radio valve, by drawing in electrons from outside, multiplies by about 200 the number of electrons responding to the impulse in the previous one, so that for each electron in the accurately manœuvring swarm entering the amplifier there will be ten million electrons in the equally accurately manœuvring swarm emerging from it. The impulses of this swarm are then impressed on the lamp 'D' which converts them from electrical impulses into exactly equivalent modulations of the beam of light 'E'. Here the beam of light, still bearing within it these modulations, impinges on the photo-electric cell 'F'. As was explained above, when light falls on one of these cells, electrons are set free within it exactly proportional in number to the intensity of the light. So the

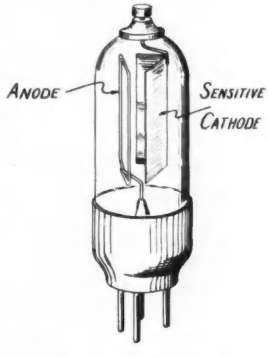
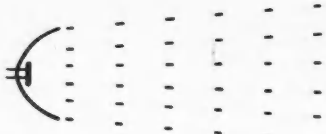
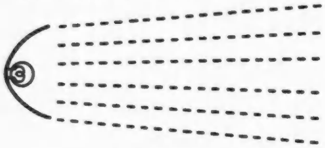


FIG. 10.—A photocell.



Short-wave transmitter with reflector.



Optical projector.
FIG. 11.

photo-electric cell 'F' responds accurately to the light modulations, and converts them again into electric impulses. But as they are very weak they have to be passed again through an electron amplifier 'G' with its radio valves, ready to be converted finally into sound waves in the air by the loudspeaker 'H'. This will reproduce the sounds which originate with the gramophone record 'A'.

In the whole train of events, including amplifiers, the impulses have been converted and reconverted six times in addition to nine stages of amplification.

Is it not very significant that we are able to translate at will such an enormously rapid and complicated train of waves (which make up human speech or the music of instruments) into electric impulses or light variations or photographic or mechanical impressions and lose little as regards faithful reproduction after all these metamorphoses?

After this it may not be so difficult to realise that liberated electron apparatus is now made in which the inertia of these very light electrons actually plays an essential part in the creating of oscillations which can have a frequency of well over three thousand million per second. Such oscillations are so rapid that we can begin to treat them as if they were radiations from a source of light, for, of course, they are of the same nature as light. We can put a small aerial, a few inches long, in the focus of a reflector to radiate them much as we put a lamp in the reflector of a motor headlamp to concentrate and radiate light, and the wireless beam is projected forward like that of a headlamp (Fig. 11). The use of wireless beams of this frequency is to send speech or signals over short distances with simple and compact apparatus. In the form of radar it was one of the major agencies which contributed to victory in the last war.

The Electron Microscope

Another application of liberated electrons is their use for magnification purposes. This is interesting for two reasons; firstly, because of the extraordinary detail which can be revealed in the objects so magnified. Secondly, because of the somewhat incomprehensible attribute of electrons in that a swarm of them, travelling at very high speed in a vacuum, constitute a beam which behaves in some respects like a beam of light—and may be some 100,000 times finer in its texture. This fineness of texture enables the beam to be used as a much more discerning form of probe than if it consisted of ordinary light.

Electron microscopes have been constructed to take advantage of this. The result is that, whereas the ordinary microscope can show the detail of objects up to a magnification of 2000 times, the electron microscope can extend the magnification to 100,000 times—if we want it. It is not often, however, that so high a magnification is needed.

Lighting

Until a few years ago we in our homes and buildings had as our means of lighting little but the electric filament lamp. The procedure in getting light from this is to make the electrons travel along a fine wire inside the electric bulb and to crowd the electrons together so much that they make the wire white hot—so hot that it gives out light.

Whenever electrons escape from the wire in this kind of lamp they tend to harm the lamp and special precautions are necessary to keep them within the filament. The tungsten filament lamp is a beautiful example of scientific and technical skill and although it may one day be superseded, it will always remain a major industrial achievement.

Nevertheless, an investigation of alternative sources of light was started some twenty years ago. The starting point in that search was the discharge in vacuum. The key to this phenomenon was the electron, for the glow which is obtained is the result of encounters at high speed between electrons liberated from the metal, and residual particles of the nitrogen from the air, which move about in the tube in a random way. These molecules are over a thousand times larger and heavier than the electrons, but as the electrons travel in the tube at speeds of some six million miles per hour—they produce some unusual effects on the molecules when they collide with them.

In this process an electron excites its molecule in such a way that the molecule sends out a flash of light or of ultra-violet. That is the light which is seen in the glow; it is the accumulation of the effects of millions of millions of these electronic encounters every second.

What colour is the light flash? That depends upon whether the molecules in the tube are those of nitrogen or oxygen or mercury or any other gas or vapour. Each one has its unique colour signature.

For instance, the carbon dioxide glow has colour-revealing properties nearest to those of daylight but it does not give much light.

The rare gases argon and krypton also give but little light, and are respectively whitish blue and purplish white in colour.

Perhaps the most striking of these gas discharges are neon and helium, bright red and buff white respectively, and giving a fairly good light output.

Each one of these glows is occasioned by the electrons charging into the complex structure of the individual molecules and exciting them so that they emit light having these beautiful colours; each gas has its own particular colour and its own particular way of revealing or of distorting the colour of objects.

Coloured light is attractive to look at—witness the neon signs which decorated the façades of West End

buildings in the pre-war days when there was abundance of electricity. But coloured light is anything but attractive for lighting rooms or streets or people.

So if our newly-gained knowledge of the electron, and its way with the gas molecules, were expected to result in practical lamps for the interior of our domestic or our public buildings, some other line of approach to the problem seemed called for, which would yield a lamp whose light would enhance and not distort the beauty of the scene.

It is natural to ask what is wrong with the old kind of light from the filament lamp. The light itself is tolerable if not very good, and the filament lamp is a simple and inexpensive article. The answer lies in another question, which has lain at the basis of all electric lighting progress for the past sixty years. How much electricity does the lamp use to give us the light we want?

These islands use something like 4000 million units of electricity every year for electric lighting. That means nearly 2½ million tons of coal each year. If we had to give the same amount of light but using the kind of filament lamps which represented the best practice 50 years ago, we should be needing 8 million tons of coal and 6 additional electricity stations the size of Battersea power station. That shows, incidentally, the result of progress made through research by the electric lamp industry over these 50 years.

But Industry must always search for something better than its present best and it was imperative to see if these gas-discharge light sources could be made to yield another step forward in the efficiency of converting electricity into useful light. The result is coming up to the most sanguine hopes of those who started upon the exploration.

It began with the rather unpromising-looking mercury vapour tube. In this the electrons cause the molecules of the vapour of mercury in the tube to emit several colours of light, which, when mixed up together, emerge as a bluish hue. Such a tube as a light-giver is no more efficient than the ordinary electric lamp.

The upper diagram of Fig. 12 shows the actual colours which the mercury molecules give out. If they are compared with the spectral distribution in the lower diagram it can be seen that there is virtually no red, but there is a very strong amount of green and some blue and yellow. There is also something substantial to the left which has no colour—and is also not visible because our eyes are not sensitive to it. But it is there as ultra-violet radiation, which the electrons stimulate in the same manner as they do coloured radiation. Can we use this 'black light'?

The answer is to be found in the application of fluorescent materials. The strong ultra-violet radiation cannot get out through the glass as can the coloured light radiation and we could not see it if it did. But the ultra-violet component can be converted into visible light by coating the inner surface of the tube with a thin layer of a suitable phosphor.

The charm of this is that we are getting all this extra light for nothing. Under the stimulation of the electrons the mercury molecules give out ultra-violet whether we want it or not. It uses no extra electricity for the fluorescent material to absorb the ultra-violet light and turn it into brilliant visible light.

This increases the yield of light from the lamp very

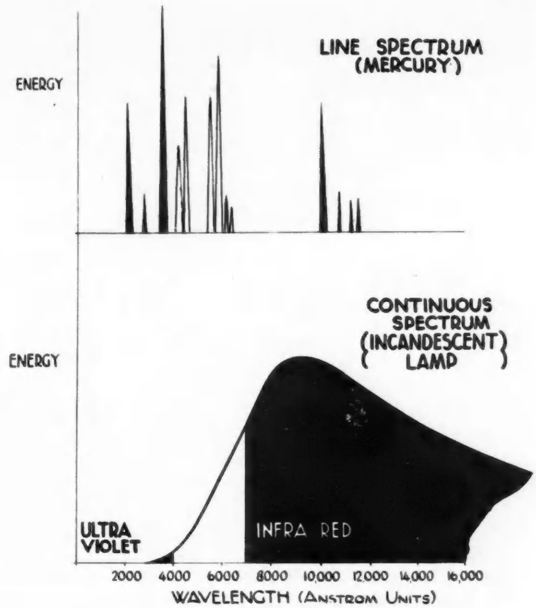


FIG. 12.—Energy distribution in continuous and line spectra (not to same scale).

greatly. We now get three times the amount of light for the electricity we use compared with the older type of electric lamp. What does this mean in terms of coal and electricity? Although most industrial and public buildings are tending to change over to this more efficient lighting, we know that it must take some years to replace a substantial proportion of the present filament lamp lighting, particularly that in private houses.

If for a moment we assume that one day all electric lighting will be by the new lamps, it would save us nearly two million tons of coal a year and two large generating stations the size of Battersea. These figures assume that the total amount of electric lighting will not increase over the next five or ten years. But, of course, it will, and the potential saving therefore becomes greater. However, in all these estimates allowance has to be made for the demand by the public for more light as well as for the use of less electricity.

Attention has been paid more particularly to the fluorescent lamp because its prospective utilisation covers 95% of the practical electric lighting field. But there are situations (such as in street lighting) for which these lamps, because of their large size, are not always well-suited. For such applications we usually want a large amount of light from a small source.

For this purpose we have to create a very great concentration of electrons and of gas molecules, so that their light-producing processes have to function in a confined space. We cannot in this case use fluorescence to help us because there is not enough ultra-violet, and anyway the heat is too great for our fluorescent materials. We have to draw our light direct from the interaction of liberated electrons and gas molecules. Therefore, as we have seen, the colour of the light is much more difficult to control.

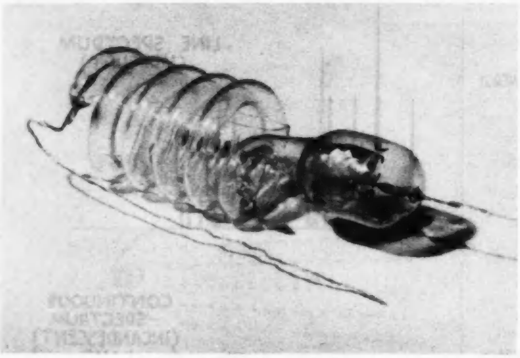


FIG. 13.—Stroboscopic lamp.

I am afraid our modern street lamps witness to the fact that in this respect the problem is only half solved! But the mercury and sodium vapour lamps as so far evolved for such purposes as street lighting are so efficient compared with the older types of lamps that the colour drawback has to be accepted—particularly in this period of temporary electricity shortage.

There is, however, some hope of progress towards whiter light, particularly with very high power concentrated lamps, such as that developed for film studio lighting in which the colours of the human face are much more natural than with the mercury or sodium vapour lamps.

The Stroboscopic Lamp

Another interesting device in which the special characteristics of electrons are used is the stroboscopic lamp (Fig. 13).

A tube containing krypton gas, instead of having in it a continuous stream of electrons to act on the gas molecules, is designed to give repeated and very powerful bursts of electrons lasting for only a fraction of a second. Each burst will generate an intense flash during the brief period it lasts, followed by a long dark period until the next light burst is due. The electrons respond so immediately to control that these bursts can be restricted to one-millionth of a second duration each. They can follow each other at the rate of several thousand per second if desired.

If a very short burst of light illuminates a rotating object only at a fixed moment in its revolution, one's eyes obtain as it were an instantaneous photograph of it in that position once each revolution. They retain that image during all the rest of the revolution when the picture is not illuminated, so that it appears that the object has been stopped in its rotation.

The interest of this equipment lies in the great intensity of the flash and the extreme shortness of the instant during which the electrons are in action, resulting in the very sharp definition of the picture. It may well have many applications, such as, for instance, the examination of rapidly rotating machinery.

We may say that Joseph Thomson liberated the electron and by so doing made it available for great uses. It is a great thing to liberate a great truth as he did from the obscurities and prejudices which surround it, and to send it out into the world to do great and beneficent work. There are many truths both spiritual and material which are held in obscurity by prejudice or ignorance. The world will be the better for their release too—that like the electron they can be set free to accomplish their destiny in the lives of individuals and nations.

Metals for Gas-Turbines

THE gas-turbine, in its present successful form as the motive power of the jet aeroplane, and in its approaching applications to land and marine service, is the world's most successful heat engine, with thermal efficiencies surpassing those of the steam-turbine and the Diesel engine. This has been achieved by considerable advances in design over pre-war practice, but also by rapid progress in the metallurgy of its components, which has been largely concentrated in the last seven years.

The parts of the gas-turbine subjected to the severest conditions are, of course, the turbine-disc and its blades, and an estimate of the metallurgical advance which has been made here can be formed from the fact that, while in the decade before the war operating temperatures were in the region of 500–550° C., today they are in the region of 750–800° C., with the attainment of 900–1000° C. as an immediate objective of designers.

These advances have not been made, however, entirely as a result of development in the gas-turbine alone; practice in steam-turbines, in exhaust turbo-superchargers, in chemical engineering, and in many other high-temperature fields has also contributed, because, basically, the conditions endured by gas-turbine blades are an extension and a combination of the conditions in those fields.

The turbine disc, and especially its blades, are subjected to centrifugal force, which imposes tensile stresses of 14–16 tons per sq. in., to gas pressure, which contributes a bending stress of 2–3 tons per sq. in., and to cyclic variations of stress which, though much less in amplitude, have frequencies of 1000–5000 per second—all this at a temperature at which the common metals and alloys are extremely plastic. Naturally some yielding is inevitable, and is allowed for; it is known by the descriptive name of 'creep', and the permissible rate of creep in aircraft jet-engines is of the order of 0·0001 in. per in. per hour. Moreover, while a life of 300–1000 hours is satisfactory for an aircraft jet-engine, the manufacturer of a unit for land or marine service will demand 75,000–100,000 hours trouble-free service, and therefore have to consider that undesirable factor, 'fatigue'. The plain fact of this is that the load a metal will bear when it is applied and then taken off, or significantly reduced, rapidly and repeatedly is far less than it will bear continuously. Stress-causing vibrations are thus deadly to metals where long service is required, and must be eliminated through careful design.

Besides softening metals, heat also destroys them; air and the products of combustion produce oxides which, in the majority of cases, are weak and easily removed.

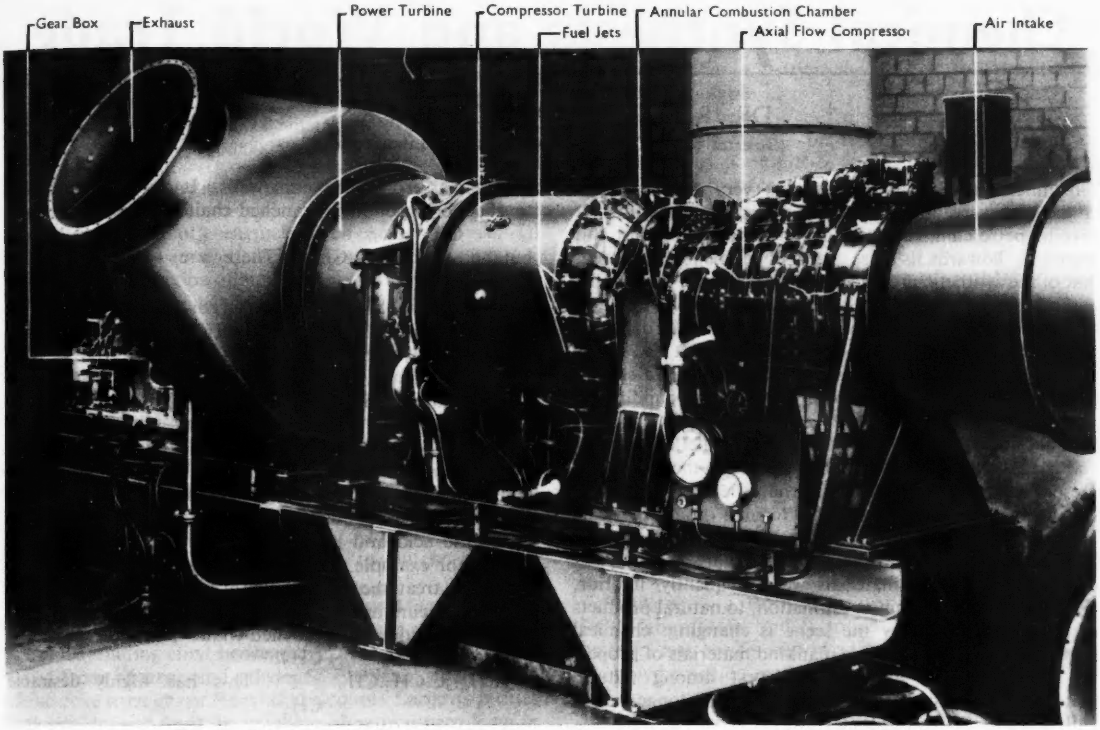


FIG. 1.—The first gas-turbine engine went to sea this summer in a motor gun-boat of the Royal Navy. Its discs and blades were made of steel specially developed for such engines.

Exceptional in this respect are chromium, nickel and cobalt, whose oxides are strong, impervious and tenacious; stainless steels owe their corrosion resistance to a film of chromium oxide from the chromium they contain. These particular metals also have a particular property which greatly contributes to the strength of the iron alloys of which they form part—that of forming 'solid solutions' with iron at a high temperature which, on quenching (accelerated cooling), retain the high-temperature modification of iron, known as gamma-iron or austenite. This modification of iron dissolves its own, and other, carbides, and by tempering very high strength can be developed, which is still retained at high temperatures. One such alloy as these is the British G 18 B, containing 0·25% carbon, 13% chromium, 13% nickel and 10% cobalt; the great complexity of such a steel is shown by the fact that in addition it contains 2% molybdenum, 2·5% tungsten, 0·8% manganese, 0·4% silicon, and 3·0% niobium, all of significance. Niobium in particular plays an important part in stabilising the alloy.

Iron unalloyed and normally cooled exists at room temperature in another form known as ferrite, and steels based on this, and strengthened by smaller but very important additions of molybdenum and vanadium, have still some applications in the gas-turbine field. For example, the power-turbine of the Metro-Vick engine fitted in MGB 2009, the first sea-going gas-turbine in the world (Fig. 1), has discs and blades of such a steel. The blades of the gas-generator turbine, in whose exhaust-stream the power-turbine runs, are, however, of Nimonic 80, typical of the next group of alloys to be considered.

The term non-ferrous, of course, includes all metals other than iron, and all alloys in which that metal does not play an important part, but very few non-ferrous metals or alloys have anything like the heat- and stress-resisting properties of iron alloys; and in these the metals nearest in properties to iron preponderate. Typical is Nimonic 80, which contains 75% nickel, 21% chromium, 2·5% titanium, and 0·7% aluminium; this alloy is standard on De Havilland gas-turbines.

There appear to be no serious problems in the compressor that known light alloys, or in extreme cases, normal stainless steels cannot deal with; a typical light alloy, to be heat-treated by a process similar to that described for Nimonic 80, would be RR 58, with its 2% copper, 1·5% magnesium, 1·2% nickel, 1·0% iron, 0·2% silicon and 0·05% titanium—the rest being aluminium.

It is in the turbine, then, that we may expect the widest departures from normal engineering practice, as temperatures rise. Ceramics, such as quartz, fused alumina and silicon carbide have several obvious advantages for high temperature, in great heat-resistance and mechanical strength, and with increased inlet temperatures, efforts will certainly be made to use them; but since considerable changes of design would be necessary to make the best use of their properties without encountering their disadvantages, such as susceptibility to thermal shock, it is more to be expected that attention will be given to cooling blades and discs in the present basic designs. In that case, the present metallic alloys and their descendants will probably give good service for some years to come.

PATRICK SAVILLE

Chemical Synthesis and World Trade

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(Director of the DSIR's Chemical Research Laboratory.)

THE nineteenth century witnessed a very great increase in the discovery and use of the materials of nature. It gave us petroleum, rubber and morphine; aluminium and uranium. Towards its close a new phenomenon appeared, that of the synthetic production on a large scale of valuable natural materials by methods devised in the laboratory and not proceeding in living matter. The synthetic dyestuffs alizarine and indigo led this movement. But the terms *synthesis* and *synthetic materials* are also used in a second and wider sense—they can be applied to the building-up of materials which are entirely artificial and not encountered in nature at all. It is this aspect of synthetic chemistry and chemical technology which has come to the fore in the present century. The result is that the technologically useful organic materials available to man on a large scale are now no longer restricted to those produced by the biochemical processes of plants and animals.

At first synthetic materials were frequently inferior, either in fact or in common estimation, to natural products of similar type. Today the scene is changing: chemical synthesis is beginning to give mankind materials of properties equalling and excelling the best among natural materials. 'Artificial' and 'synthetic' are no longer terms with a faintly disreputable flavour.

This remarkable development is worthy of careful study. It is already having its effects on world trade and this will become more marked as time goes on. In the pages which follow I will give some examples of the new developments and review some of the possible consequences.

Synthetic Petrol

As a first example let us consider synthetic petrol and synthetic aviation petrol in particular. Most people know that it is possible to synthesise 'oil from coal' by hydrogenation and that this process has been carried out on a very large scale both in Germany and in the United Kingdom. It is perhaps not so generally realised that for the preparation of modern specialised petrols, synthetic chemistry has now been called on to play an essential role.

Modern design in internal combustion engines has been in the direction of higher compression ratios and this has been pushed particularly far in aircraft engines. The ordinary 'straight-run' petrol obtained by distilling natural petroleum is incapable of giving the necessary performance and the addition of anti-knock materials such as tetraethyl lead provides only a partial solution. What is required is a modification of the molecular structure of the hydrocarbon fuel so as to reduce the tendency to pre-ignition, 'knocking' and loss of power. The solution is to provide more hydrocarbons of branched-chain and aromatic (that is, belonging to the benzene family) character and less of normal straight-chain paraffins. The problem has therefore been passed to the chemist and a number of solutions have been forthcoming. I will mention one which involves the preparation of a branched-chain material.

Normal butane, $CH_3CH_2CH_2CH_3$, is present in the natural gas from petroleum wells. It can be isomerised to the corresponding branched-chain hydrocarbon, *iso*-butane $\left.\begin{array}{l}CH_3\\CH_3\end{array}\right\rangle CH\text{—}CH_3$. There are several ways of doing this—one convenient on a large scale is to pass butane vapour mixed with hydrogen chloride over an aluminium chloride catalyst at a temperature a little above 100°C. The saturated butanes can easily be dehydrogenated to the corresponding unsaturated butylenes, for example by passing them over a heated catalyst of activated alumina. Butylenes are also made in the 'cracking' of petroleum at high temperatures.

The final stage in the synthesis is to combine iso-butane with butylene, by what is called catalytic alkylation. Sulphuric acid and hydrogen fluoride are valuable catalysts. For example we can dissolve butylene in sulphuric acid and treat the solution with iso-butane. A vigorous reaction occurs under mild conditions. The product contains the valuable branched-chain paraffin iso-octane

$$(CH_3)_3C.CH_2.CH\left\langle\begin{array}{l}CH_3.\\CH_3\end{array}\right.$$

This has highly desirable anti-knock properties and is in fact a standard reference material. In this and other similar ways very large quantities of aviation petrol were made for the Allied Air Forces during the recent war.

The preparation of high-efficiency fuel for internal combustion engines has thus become to an increasing extent a specialised process of synthetic chemistry.

Synthetic Rubber

The indictment of 23 directors of the I.G. Farben at Nuremberg in August 1947 has focused attention in a vivid and unprecedented way on the contribution which chemical technology, and more particularly chemical synthesis, can make to national economy in time of war or emergency. It has recently been said that the I.G. was the most important single factor in Germany's war preparations. Its main contribution was to make the Reich self-sufficient in nitrates, oil and rubber. Germany had virtually no access to natural supplies of the last of these three vital materials.

Early research in this country, Germany and elsewhere had indeed led to synthetic rubber-like materials but they were not completely satisfactory in quality. Further systematic investigation in the I.G. laboratories led to the discovery in 1935 of Buna S, which is made by polymerising butadiene and styrene together. The material so obtained, though inferior to natural rubber in various respects, was sufficiently good to become a practical proposition. In use it was mixed with some natural rubber.

A satisfactory product having been found, the essential problem now became one of the production of the intermediates on the necessary enormous scale. How large this

was is shown by the figures for the German manufacturing capacity in 1943:

Butadiene	132,000	metric tons per year.
Styrene	44,000	
Buna S	106,000	

The organic synthetic chemical industry had had little previous experience on scales such as this. The total world production of even such a well-established material as indigo is only about 10,000 tons per year.

German production of butadiene was based on acetylene. Three methods may be mentioned, one standard, the other two novel. In the standard process the raw material was coke which was converted into calcium carbide and acetylene. This was then transformed by known methods successively into acetaldehyde and aldol, and thence by hydrogenation to butane-1 : 3-diol which could be dehydrated to butadiene. In an interesting variant of this process the acetylene was made from methane by cracking or partial oxidation. A completely new route to butadiene developed by the I.G. was to condense acetylene with formaldehyde in the presence of copper acetylide. This yielded butine-1 : 4-diol which was hydrogenated to butane-1 : 4-diol and this dehydrated to butadiene.

Styrene is present in coal tar but in quantities too small for a synthetic rubber programme. It is today prepared by dehydrogenating ethyl benzene, which can itself be synthesised from benzene and ethylene. Ethylene can be made from coke oven gas or from ethyl alcohol. Large quantities are also derived from the cracking of natural petroleum in oil-refining countries.

The vast production of acetylene in Germany did not, of course, all go into Buna. The conventional uses of the gas for heat and light took up large amounts and a number of important solvents and plastics, including polyvinyl chloride, were also made from acetylene. It appears that in 1942, before bombing began to affect production seriously, the German output of acetylene reached nearly a quarter of a million tons per year, more than half going into Buna.

When Singapore fell, the Allies were faced with a somewhat similar situation. There was a stock pile of natural rubber, some available plantation rubber in Ceylon and elsewhere, and the possibilities of reclaimed rubber. But all these together were quite insufficient to meet the military requirements, let alone the tremendous civilian demands for road transport, particularly in the U.S.A. The situation was saved by the American synthetic rubber programme, hastily arranged and pushed through with great determination. It was based on the young and virile industry of petroleum chemistry supplemented by a substantial (although less economic) production of intermediates from grain molasses. The main American synthetic rubber was, like that made in Germany, the butadiene-styrene copolymer compound, and it was the method of production of the intermediates which provided the principal difference from the German development. By 1944 the annual production of the American synthetic material was approaching three-quarters of a million tons, that is, about half the total world requirements for rubber, and more than six times the German peak production. There is also a synthetic rubber industry in the U.S.S.R., but details about it are not available.

Synthetic rubber differs from the other materials mentioned in this paper, because the principal synthetic product, Buna S or GR-S, is, on the whole, inferior to natural rubber. Moreover, it is (at present prices) rather more expensive. But synthetic rubber has to be mentioned for two reasons; first because of the great economic significance of the founding of so large a synthetic industry, secondly, because there are a number of synthetic 'rubbers' other than Buna S now on the market, some of which are in certain respects considerably superior to natural rubber and are therefore valuable for specialist purposes.

Polythene, Nylon and Silicones

Synthetic rubber provides only one example of the new materials of commerce composed of high polymers. There are very many others both in the field of synthetic fibres and among plastics proper. Two materials of special interest are polythene and nylon. Both these are excellent examples of synthetic products with properties superior to their natural counterparts.

Polythene is a British discovery originating from the I.C.I. laboratories and factories. It is not only a novel material but one formed in an entirely novel way, namely by polymerisation under extremely high pressures. The process is essentially simple: ethylene is heated at 100°–250° C. under a pressure of 1500 atmospheres. A small and carefully controlled amount of oxygen is used as catalyst. The product is a wax of very high melting point (110°–115°), chemically inert, and tough. It is of particular value because of its remarkable insulating properties and it is widely used in high-frequency electrical equipment. The usefulness of the material is enhanced by the ease with which it flows in the molten state, as this makes extrusion and moulding simple. The success of radar owes a great deal to polythene.

Nylon is another excellent example of fundamental chemical research leading to a sweeping technological advance. The discovery originates from the investigations of Carothers of the Du Pont Company. Research was begun in 1928 on linear polymers such as the polyesters formed by the interaction of alcohols with two hydroxyl groups and acids with two carboxyl groups. Many promising results were obtained and these culminated in 1935 with the discovery of 6 : 6 Nylon, the polyamide compound formed from adipic acid and 1 : 6-hexamethylene diamine. This is essentially composed of a repeating pattern of hydrocarbon units joined together by amide links:

$$-\mathrm{NH}-\boxed{C_6\ \text{chain}}-\mathrm{NHOC}-\boxed{C_4\ \text{chain}}-\mathrm{CONH}-\boxed{C_6\ \text{chain}}-\mathrm{NHOC}-\boxed{C_4\ \text{chain}}-\mathrm{CO}-$$

The product formed stable fibres capable of being stretched by cold-drawing. The first large-scale nylon plant went into operation at Seaford, Delaware, in 1940 and was producing 4000 tons of nylon annually two years later. From the artificial fibre so formed 100 million pairs of stockings were made in 1941. Nylon production has now been started in the United Kingdom.

The manufacturing process, which is comparatively complicated, is worth describing in a little detail. The

usual starting materials are benzene or phenol, aromatic materials isolated from coal tar. These are hydrogenated to cyclohexane or cyclohexanol which can readily be oxidised to adipic acid, $COOH.(CH_2)_4.COOH$. Part of this acid is made into its amide which is dehydrated to the dinitrile. This is then hydrogenated to hexamethylene diamine $NH_2(CH_2)_6NH_2$. The chemical intermediates have now been made and the rest of the process consists in making the polymeric amide and converting it into fibre. For this purpose adipic acid is treated with the diamine to give nylon salt. This is dissolved in water, and heated in an autoclave to start the formation of amide. A stabiliser is added and polyamide formation is completed by heating up to 300° C., water being evolved continuously. A mass of molten nylon results. This is extruded as a film which is chilled quickly and cut up into pieces. The film is then melted under nitrogen in a pressure vessel, filtered through sand and extruded in the form of fine filaments. These fibres, in which the nylon molecules are oriented at random, cannot be used in textiles as such. They must first be cold-drawn to about four times the original length, when the molecules are pulled into a parallel orientation. Finally the fibre is twisted and woven.

This is the main form in which nylon comes on the market, but it is also produced as much thicker single filaments which are used in toothbrushes, tennis racket strings and so on.

Nylon as a polyamide chemically resembles the natural polypeptide fibres such as wool and particularly 'real' silk, rather than the cellulosic fibres such as cotton and viscose rayon.

The popularity of nylon among consumers is well known and this is based upon a number of properties which can be quantitatively evaluated in the laboratory. The main advantages over silk are: greater uniformity; the possibility of selecting the size of fibre; greater tensile strength, particularly when wet; greater elasticity and toughness; resistance to rot and mildew. The main disadvantages are: susceptibility to strain at low tension; shrinkage when wet; a lack of the warm feel and suppleness of silk.

It must be counted a great achievement of organic chemistry to have produced a synthetic material, considerably stronger than steel weight for weight, with such remarkable properties and at a competitive price. Commercial nylon is only seven years old and its applications have so far, in the main, been confined to hosiery and to military purposes. Doubtless more uses will be found. Doubtless also nylon does not mark the limit of possible advance in the field of synthetic fibres.

A brief mention must be made of the substances called silicones, not because they command wide markets or are manufactured on a vast scale but because they provide an excellent example of synthetic materials with special properties unparalleled in nature.

The class of substances today called the silicones was discovered in this country many years ago. Their commercial exploitation has been carried out in America during the last few years. They are a cross-bred type of compound in which the central core resembles that of silica, this being surrounded by an organic layer.

Silicones which are being examined in technology include oils, greases, rubber-like materials and resins. Some of the special characteristics which make them interesting are: (i) the oils change very little in viscosity with temperature and hence may be used under arctic conditions, (ii) the resins have great resistance to heat; (iii) silicone films are highly water-repellant. At present these substances are comparatively costly.

It would be possible to multiply these examples from other fields of organic substances: one could draw up a very long list of synthetic drugs, anaesthetics, pesticides, dyes, pigments, plastics and solvents of properties not paralleled among naturally occurring materials.

Instead of doing this it will be useful to maintain a proper balance by indicating some things that synthesis has *not* done. The vitally important field of foodstuffs has so far almost completely resisted the encroachments of synthesis and seems likely to continue to do so. It is true that the storage, transport and preservation of our food is becoming more and more dependent on science. It is also true that some chemical or biochemical processes are increasingly important in food manufacture, for example the preparation of margarine and of synthetic vitamins. But these do not obscure the central point: that man depends upon the land for his food.

An interesting example of a substantial effort to prepare a wholly synthetic foodstuff has recently come to light. Germany was notoriously short of natural fats and oils during the war, particularly after 1941, and this led to great interest in synthetic substitutes and a satisfactory method was devised for the production of fatty acids from available hydrocarbons. This need not be described in detail. The important point is that the various starting materials used all came from coal. In the main the acids so prepared were used as soaps in the form of their salts. But another quite new development followed. A selected fraction of the synthetic fatty acid was esterified with glycerol which had been obtained by hydrolysing inedible oils. This yielded artificial margarine; not artificial in the usual sense (for all margarine is a processed product); but a foodstuff synthesised from coal. In spite of a comparatively unpleasant taste it was issued to the German armed forces to some extent. As it contains 'unnatural' types of fatty acids—both those possessing odd numbers of carbon atoms and those with branched chains—it needs very careful testing of its nutritive value before it can be generally accepted as a foodstuff. Moreover it is uneconomic to produce.

Here then is a salutary example in which factory synthesis has failed to rival biological synthesis. We can be sure that the political conditions in war-time Germany were peculiarly favourable for a fair trial to be given to synthetic fat, but the actual production (about 2000 tons per annum) only amounted to some 0.2% of the total German consumption.

Inorganic Materials

So far all our examples have come from the organic kingdom, and this is natural enough, because it is the domain, *par excellence*, of synthesis. But if we do not interpret the term synthesis too rigidly we can find examples of comparable or even greater technological importance among inorganic substances.

Some metals are natural substances in the fullest possible sense in that they occur in the free state, for example, gold and, to a small extent, copper. With these

few exceptions all metals are made by technological processes involving the breaking down of their ores; no pure metal can, of course, be 'synthetic'. But alloys are a different matter. In the vast majority* of alloys, metals which normally occur apart are brought together artificially in selected proportions. This is a process of synthesis in the philosophic sense rather than in the usual chemical sense. In alloys the various atoms are stuck together by a 'glue' of electron in the crystal lattice whereas in synthetic organic chemistry they are joined in molecules by chemical bonds (covalencies).

Just as the controlled joining of organic groups together is beginning to give us 'tailor-made' molecules of special properties such as Buna, Polythene and Nylon, so the controlled joining together of metal atoms gives us alloys of profoundly modified characteristics. The best examples of all are perhaps the special alloy steels of today. In them the properties of the basic element, iron, is completely altered. For instance the 'stainless' steels which contain very considerable amounts of chromium and nickel and which are essential today for much of our chemical plant.

If we pass from ferrous to non-ferrous metallurgy we find the same trend towards increased complexity aiming at improved properties. A startling instance of this was Duralumin, the alloy of aluminium, copper and magnesium which becomes much tougher and harder on ageing, and was used in the Zeppelins of 1914. Complex aluminium alloys are now available which are considerably stronger on a weight basis than steel. Magnesium alloys have made great progress in the last few years and it has been found possible to prepare materials easily machined, stronger than steel and much lighter.

It would be possible to multiply these examples of synthesis in the inorganic field not only from among the alloys but among other essential materials. Synthetic ammonia and the phosphatic fertilisers provide examples of artificial chemical processes which are now essential to keep alive the vast urban population which is dependent on intensive crop production.

Consequences of Synthetic Developments

There can be no doubt that the last hundred years constitute a century of triumphant progress in chemistry and chemical technology. Man has been given a far greater command over the substances with which he must work, and the materials necessary for better health and prosperity have been and are being constantly discovered. The obvious advantages of synthetic materials in their wider choice and better performance have already been illustrated. Another factor which must not be overlooked is that, given a supply of carbon in some form and of fundamental chemical reagents, the preparation of organic synthetic substances is independent of such variables as the size of crops, rainfall and diseases. Add to these technical advantages the economic fact that many excellent synthetic materials are produced at competitive prices and the large-scale introduction of such substances is readily explained.

* Monel metal is an exception. It is in a sense a 'natural alloy' made by the working up of a mixture of the ores of nickel and copper (together with small amounts of other metals) which occurs naturally in Canada. Cast iron might also be considered to be a 'natural alloy'.

In spite of all this, there seems, in some quarters, to be an instinctive reaction against synthetic materials. This may arise from a diversity of causes. The historical association of natural materials with the honourable pursuit of husbandry; and a mental connexion between synthetic materials and inferior ersatz substitutes, and with war. These are perhaps matters for the psychologist. If the position is fully examined this standpoint can hardly be maintained. It is difficult to hold that it is a good thing to extract cocaine from a natural leaf but a bad thing to synthesise sulphanilamide.

At the other extreme are those who acclaim without reserve every technological advance involving synthesis. Scientifically this is entirely justified, but from the economic and social points of view certain difficulties arise. The central difficulty is that changes from the natural to the synthetic, tend to transfer production from the country to the town and particularly to the more technically efficient and highly industrialised states. Added to this in the case of organic materials there is the difficulty that technologically advanced states with an adequate supply of coal or oil tend to become increasingly independent of agricultural communities which produce specialised natural materials, such as quinine and rubber. The latter difficulty does not arise with metal alloys as, although the production of the alloys will tend to be concentrated in industrial areas, the raw materials will continue to form an important part of international trade. With this important exception, however, the development of improved materials, synthetic in the broad sense, will tend to a state of disequilibrium in trade which will be to the disadvantage of agricultural communities, notably in the tropics. A classical example lies in the effect of the German synthesis of indigo on the plantation industry of Bengal.

Not only can such results arise as a consequence of the ordinary march of scientific discovery and industrial application, but it is possible for nations to adopt economic self-sufficiency as a deliberate policy and to use synthesis as a method for securing it. Such was the policy in Germany in the 1930's, of which Buna rubber was one outcome. The motive behind the policy was the strategic preparation for war.*

These are very real difficulties; but it may be said that there is a very simple solution—to call a halt to research and technological developments based on synthesis. The argument would run roughly that world trade is already sufficiently out of equilibrium, that existing materials are good enough and that the game is not worth the candle. In my view this argument must be rejected both as a matter of principle and because (like many other restrictive solutions) it would not work in practice.

The problem therefore remains that from a broad point of view technological advances cannot be welcomed in isolation, and that the consequential alterations in trade will have to be reviewed with responsibility by those concerned. It is perhaps not a very long-range problem, but it may last for the next few hundred years while a capital reserve of carbon lasts and while the political organisation of the world remains in its present pattern.

* This aspect is developed further in the writer's recent lecture 'Chemistry and Autarchy' (*Chemistry and Industry*, July 12th 1947, p. 417).

FAMOUS SCIENTIFIC INSTITUTIONS—VI

The G.P.O. Research Station

A. W. HASLETT, M.A.

THE Post Office is the biggest single user of electrical equipment in the British Isles, and correspondingly has the biggest research establishment of any governmental user organisation. This is by no means a wholly modern development, and in particular the part played by Sir William Preece, Engineer-in-Chief to the British Government Telegraph Service at the close of last century, both in his own radio research and the encouragement of Marconi, then a young man without name or influence, has been too little recognised. That story has been well told by the late Sir Ambrose Fleming, and goes far to explain the adoption of an organised research policy by the Post Office some seven years later.

"In July 1896", Sir Ambrose wrote, "Marconi introduced his invention and new method of telegraphy to the notice of Sir William Preece, who had for the previous twelve years interested himself in the development of wireless telegraphy by the inductive-conductive method. On June 4, 1897, Sir W. H. Preece gave a lecture to a large audience at the Royal Institution of London on 'Signalling through Space Without Wires'. After expounding older and other methods, he devoted considerable time to exhibiting and explaining the Marconi apparatus." He spoke of the demonstrations which had been given between Penarth in South Wales and Brean Down near Weston-super-Mare, over the same stretch of the Bristol Channel, across which the Post Office more than thirty years later was to conduct its own first trials of ultra-short-wave telephony; and he stoutly defended Marconi against the accusation that, because he had made radio practical, he had done nothing new. "Columbus", he said, "did not invent the egg, but he showed how to make it stand on its end."

The picture, in short, is of an organisation which, even if it possessed no building which bore the title of research laboratory, was none the less both active in research and ready and generous in its appreciation of research by others. Formal research was inaugurated in 1904 in a few odd laboratories in the city. The date is worth noting in relation for example to the establishment of the Advisory Council for Scientific and Industrial Research (the parent body of the D.S.I.R.) in 1915. But it was not, in fact, until the end of the first World War that research activity began to expand at any serious rate, nor would this have been physically possible until a site outside the congested city area had been secured.

Laboratories at Dollis Hill

The present laboratories at Dollis Hill date from 1921, when a site of eight acres was secured in what was then practically open country—and, incidentally, at as high an elevation as could be obtained close to London. The freedom from noise and vibration which this site affords, although still useful, was practically essential with the measuring instruments which were in common use when the site was chosen. Permanent buildings, now increased to twenty in number, were formally opened in 1933, and a further two-and-a-half acres site immediately adjoining has since been acquired to allow for future expansion. As a rough indication of the scale of activity, the total staff at the present time numbers about 860. Of these about 460 are engaged on experimental work, and the remainder in the extensive workshops which have been provided. One reason for the high proportion of the latter is that it is accepted policy to carry development of devices intended for practical use to the stage when a completed article, engineered to production standard, has been produced. Anyone who has had experience of the war-time delays which sometimes resulted from research specifications, that ignored the later problems of the producer, will appreciate the reasons for this policy.

Organisation demands a word of explanation. At the head of the family tree is the Engineer-in-Chief of the Post Office. He is responsible for some 18 branches, covering for example telegraphs, staff, radio development, transmission and lines—and research. Immediate responsibility for the latter rests with the Controller of Research, Dr. W. G. Radley, who is directly responsible to the Engineer-in-Chief, Mr. A. J. Gill. In addition, further research is also carried out, not necessarily at Dollis Hill, by the radio development branch. Both branches have their own laboratories at Dollis Hill, and the line which divides their work is often as narrow as the physical separation between them. The distribution of buildings suggests a close degree of interlocking, and the impression of a visitor is that work and ideas pass as readily between the two branches as does the visitor himself. Mr. Gill's own interest in research is sufficiently indicated by the fact that he was actively concerned with the early experiments in ultra-short-wave telephony already mentioned.

Outside the Post Office, there is quite an elaborate system for securing co-ordination, on paper at least, between practically all possible agencies engaged in research. As examples, the Post Office is directly represented on both the Radio Research Board of the Department of Scientific and Industrial Research, of which it for many years provided the chairman, and also on the British Electrical and Allied Industries' Research Association, which is one of the three largest co-operative research associations in the country. Finally, the British Telephone Technical Development Committee was set up about 14 years ago to co-ordinate development work on telephone exchanges and subscribers' telephone equipment as between the principal manufacturers and the Post Office. To this established machinery must now be added Sir Stanley Angwin's committee, lately set up under the aegis of the Department of Scientific and Industrial Research to "formulate in detail the basic or fundamental problems in telecommunications which require investigation".

Work on Submarine Cables

FIG. 1.—The main block of the G.P.O. Research Station at Dollis Hill.

With this background of organisation, a few examples can now be given of researches lately carried out at Dollis Hill, which while complete in their immediate development are of continuing interest. The first is the use of submerged repeaters to increase the channel capacity of submarine cables. The essential problem in this case is that the number of conversations which can be transmitted over any particular length of cable depends on the frequency range which the cable is capable of transmitting at an adequate signal-to-noise ratio. And the latter, in turn, depends not only on the length of the cable, but on the ability to amplify at suitable intervals the speech currents, which it is the main function of the cable to transmit. On land, this need for amplification is taken for granted in modern practice, and valve-operated repeaters are in fact inserted at intervals varying from about 5 to about 40 miles. Maintenance is appreciable, but insignificant in relation to the cable economies effected; and an additional saving of some £68,000 a year has been effected by the gradual introduction of a new type of amplifier which was developed at Dollis Hill in 1938. The question therefore arose of whether a similar increase in channels could not be effected on submarine routes, and in 1943 the first submarine repeater installation in the world was laid in a cable linking Holyhead and the Isle of Man. This cable was originally operating on a frequency band of 12–108 kilocycles in one direction, and 132–228 kilocycles in the other, twenty-four two-way speech channels being provided. By the use of a repeater unit, it has become possible to use the whole original frequency band in one direction, without amplification, and to provide communication in the reverse direction, through the repeater unit, on higher frequencies which could not before have been used. The capacity of the cable has thus been exactly doubled, the frequencies used being 36–228 kilocycles about 312–502 kilocycles respectively. A rather more ambitious project for introducing a number of amplifiers into two cables to Holland is now being studied. The original cost of these cables was £160,000, and the proposed scheme will increase the number of circuits from 30 to 120 at comparatively little cost.

Several practical problems arise in any such installation. The first and most obvious is the pressure of water which the installation will have to withstand. Existing equipment is designed to stand a pressure of 1000 lb. per sq. in., was tested during development at Dollis Hill up to 500 lb. per sq. in., and has in fact been laid at a depth of 35 fathoms giving a pressure of 93 lb. per sq. in. It is in the form of a pressure-chamber of 5 ft. in length and 14 in. diameter, with an inner brass cylinder intended to be proof against only minor leakage into the outer chamber. The complete installation is essentially a pressure-proof junction box, and in no sense a part of the cable itself. This is an essential requirement for the immediate purpose of obtaining more use from existing cables. It has been emphasised in view of more ambitious schemes, which so far exist only on paper, for the provision of Transatlantic repeater cables. In the latter case the pressure to be withstood would be as much as 2½ tons per sq. in., and the repeater units would have to be designed as part of the original cable system, and not inserted into it at a later date.

Life of Valves

Another requirement, which in the long run may have the widest interest, is that of life of valves. At the time when the Isle of Man cable was designed, no suitable valves were in existence with a probable life in excess of 20,000 hours. It was recognised in advance that the development of suitable valves, with a probable life appreciably longer, would necessarily be a long-term development. Simple arithmetic is enough to show that if 40,000 hours were taken as the target—and any less improvement would hardly be worth serious effort—the better part of five years would be needed for the life-testing of a single design of valves. Such developments are not excluded, but in the meantime standard commercial valves are being used of a type (V.T.200) which was already available. The life of individual valves is estimated, after preliminary 'ageing', at $20,000 \pm 5000$ hours with 50% confidence. The design allows for the use of three alternative valves in each of three stages, with either automatic or manual switching between the various possible combinations of valves, in the event of failure. On this basis, the calculated life of such a repeater is $49,000 \pm 7000$ hours with 50% confidence—in other words somewhere between

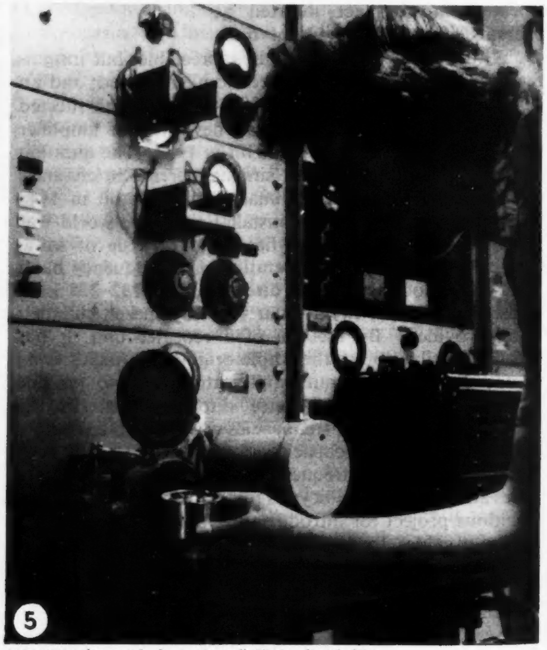

FIG. 2—Recordings on glass discs are being increasingly used, because of their durability, to convey routine instructions in trunk telephone exchanges, to record special tones and noises for the testing of telephone instrument designs and radio valves. At the G.P.O. Research Station first recordings are made on film sound track and copied photographically on to the glass discs. Here newly photographed sound tracks are being inspected visually. FIG. 3—This photograph shows the contrast between a new high-frequency multi-channel coaxial cable and an old voice-frequency multi-pair cable. The new cable carries 660 conversations simultaneously over each coaxial pair while the old one has 540 separate pairs of wires for 270 conversations.

FIG. 4—The G.P.O. Research Station cuts and mounts quartz crystals used for controlling clocks and keeping B.B.C. stations on their right wavelength. Here the quartz is being cut by means of a steel disc, studded with diamonds and revolving at 5000 feet a minute. FIG. 5—Here the newly assembled quartz crystal unit is about to be tested for frequency of oscillation.

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5 and 6½ years. While this is a long time, by normal standards, for any valve-operated device to be expected to survive without maintenance, it would clearly be of considerable advantage, for this particular application, if it could be extended.

A second example of research which has reached the stage of practical application, but which is also capable of further extension, is the use of voice-frequency signalling to afford automatic dialling and switching on long-distance telephone circuits. Connexions at a local automatic exchange is effected through direct current impulses, the coding of which is controlled by the subscriber's dial. This provides a simple and satisfactory system for the purpose for which it was intended. But, apart from the usual loss of signal strength with distance, any method of control which is based on direct currents would be automatically barred by the long-distance repeater units which have just been discussed. These will only pass alternating currents in the range of speech frequencies, and any long-distance signalling system must therefore conform to this requirement. Such a system has, however, been devised and is now in operation over nearly three thousand long-distance circuits in Great Britain. The signal frequencies used are 600 and 750 cycles, and the main problem in design was to avoid interference between signals and speech.

Extension of Automatic Telephone

Two forms of extension are possible, both of which involve policy considerations. One is the extension of automatic dialling facilities by the subscriber. At the present time, when a subscriber on an automatic exchange wants a trunk call, he first obtains the trunk operator by normal direct current signalling, and the operator then obtains the wanted exchange, or proceeds some distance towards the wanted exchange, by voice-frequency signalling. Both processes are automatic, but the transition from one to the other is effected by human intervention. There is no technical reason why the transition also should not be made automatic, and it would seem probable that sooner or later this will be done. But it will be obvious that it would involve extra complications in the metering and recording of calls; in dialling codes and procedure by the public; and not least, under present conditions, in maintenance time. None of these are research problems, but they necessarily arise in the carrying of existing research to its logical conclusion.

The second possible, but independent, extension is to international telephony. It would be within the power of the Post Office to extend through-calling from any exchange operator to any international exchange which is directly linked with Britain. It would also be possible, but beyond the powers of any single country, to retain the existing system of international exchanges, but to introduce automatic signalling between and through them; so that, for example, a London operator could call directly an Athens operator, although the call would in fact pass through a number of intermediate exchanges on the way. (Such problems are the concern of the Comité Consultatif International Téléphonique, the C.C.I.T., whose function it is to make recommendations regarding such standardisation as may be necessary to the development of international working, and to exchange research results relating to basic problems common to member countries.)

Other recent and current work can only be briefly summarised. The coaxial cable system, now coming into use, was designed and installed by Post Office engineers, and was the first system of the kind in the world for public use. In radio telephony, there has been success within limits in making good the results of fading. Much research, which is still continuing, has been done on the recording and reproduction of speech. For the Medical Research Council there was extensive and valuable research to discover the characteristics of a hearing-aid which would be of use to the great majority of deaf people. This is a piece of research which has long been needed. The lack of it brought to a virtual standstill the work of a B.M.A. committee which sought to investigate the same subject immediately before the war. In the hands of the Post Office, this research was carried to the point of a complete equipment, suitable for large-scale production, and making use of miniature components originally developed for war use.

Two war-time contributions demand special mention. The first was the production of quartz crystals for use in the control of radio frequencies. This was a line of development which the Post Office had undertaken, at Dollis Hill, well before the war because, as Mr. Gill has lately stated, "we could not get anybody in this country to make quartz crystals suitable for our purpose". During the war production became a matter of urgency for many purposes, among others for one form of radar navigational aid. The position at the time was that Dollis Hill possessed the only laboratory in Europe which could make crystals of the required degree of precision. And a technical committee on quartz, set up by the Services, of which a Post Office representative was chairman, visited every manufacturer's works in turn to ensure that proper methods were being followed. The Post Office, in turn, benefited from manufacturers' experience. But the essential point is that, without the pre-war development carried out at Dollis Hill, there could have been no rapid production of crystals for Service use, nor is it likely that British industry would have attained its present satisfactory position in this department.

A second contribution was in home defence radar. Here the Post Office was responsible for a whole variety of jobs of which one only can be mentioned. This was the relay system which was used in the conversion of the ranges and bearings supplied by one early form of radar equipment into the grid references required for operational use. A variable correction had to be applied to bearings, dependent on the siting of the particular station concerned, and further complications arose on the handling of the information on which height measurements were based. None of this, it is true, involved any principles or methods which were radically new. It was merely a rather complicated job of design and development, which for quick and satisfactory results called for wide experience in this highly specialised field of work. The result was the piece of equipment known as the 'fruit machine'. It presented the results of its calculations in illuminated figures, and proved so reliable in its working as to be taken completely for granted except by the one specialist who looked after it at each station.

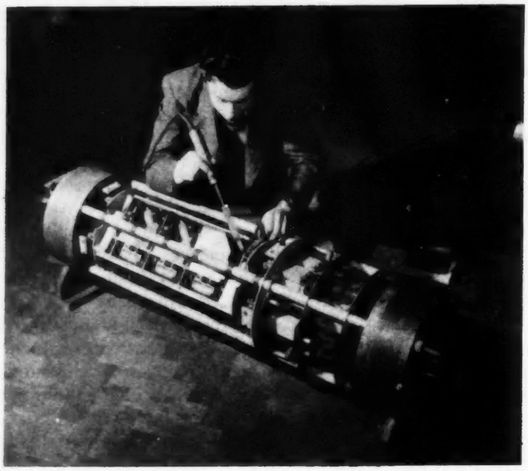


Fig. 6.—Interior of a submarine cable repeater.

At the present time, Dollis Hill is suffering from many of the same difficulties which confront other institutions. There are problems arising from the conversion from war-time work to peace, and shortages both of personnel and equipment. The present staff totals about 860. Comparison with the Bell Telephone Laboratories in the United States, where at least a thousand fully qualified engineers and scientists are engaged on research work proper, as distinct from development, certainly does not suggest that Post Office Research has been unduly expanded. Until lately, the strictly comparable staff at Dollis Hill numbered 115; this is being increased to a total of 150, and a further increase to 190 is proposed. The main difficulty, however, has been in getting the staff.

As regards internal promotion and training, the 'workman grade' entrant is treated as an apprentice, trained for two years or so and given an opportunity of promotion, either by open or internal examination, to the grade of assistant engineer. Many also come in as 'youths in training' and take one or other of the same examinations. At a later stage, they may sit the examination for engineers, and in some cases study at the same time for an engineering degree. Finally, although no comparable Post Office scheme has yet been introduced, attention is being given to the Admiralty plan by which suitable cadets are sent to a university.

Apart from the usual problem of accumulated war-time needs, and the holding up of normal research projects by war work, physical congestion at Dollis Hill has been increased by the presence on the same site of the Post Office's central training school. New premises have been taken for the latter at Stone in Staffordshire and the school, when transferred, will become residential. This will give some relief and, in addition to the space occupied by the school, there is room still available on the original site for the construction of additional workshops which are badly needed. These, together with equipment, would cost in the neighbourhood of £100,000 and would relieve what is at present the chief immediate bottleneck in the work of the station. Sooner or later, perhaps in seven to ten years' time, the difficult question will arise whether further needs can be met on the Dollis Hill site, including the reserve site already mentioned; or whether it would be sounder long-term policy to move the whole of the station to a less congested area, further removed from London. Some loss of liaison would be inevitable, both scientifically and with headquarters—but this may have to be accepted. In the meantime, it is a tribute to the degree of foresight shown after the last war that there should still be some space available at Dollis Hill.

In one other respect, the station is fortunate among Government research institutions. As a user department, it is possible for the Post Office to follow up the results of its own research, and to express in figures the economies to the Treasury and taxpayers which have resulted. There are many striking examples. For instance, the doubling of the capacity of a submarine cable by the installation of repeaters is equivalent to saving £100,000 for a new cable. This is a very sizeable contribution to the annual total of £176,000 for the wages and salaries of the Research Branch. The biggest savings, however, are those which, like the wage bill and other expenses, are annually recurring. That resulting from the voice-frequency system of dialling for long-distance calls is already estimated to reach £130,000 a year, with further possibilities of development. The speaking clock, better known as 'TIM', brings an average annual profit of £90,000. Again, early work on carrier telephony and the reconditioning of cables designed for audio-frequency working is still worth £200,000 a year, while some share could also be claimed in later work along the same lines in which industry also has played a large part. Finally, the biggest saving of all—estimated at £400,000 annually—is attributed to so simple a matter as the introduction of precise and objective methods of assessing the quality of receiver instruments. The point, in this case, is that uncertain instruments, with the larger tolerances allowed to manufacturers, would have necessitated heavier gauge cables for more distant subscribers; and the savings figure quoted is the annual equivalent of the capital expenditure which would already have been involved.

Apart from these direct and calculable savings to the taxpayer, Dollis Hill can point also to a number of examples in which its work has helped British industry, and so contributed indirectly to the nation's balance sheet. The recent example of quartz crystals has already been mentioned. Another illustration is voice-frequency signalling, similar apparatus having been installed by a British firm in Australia. In such cases, there is no immediate benefit to the taxpayer, since the attitude of the Post Office has been that its development work is most likely to be used to full advantage if made freely available to the manufacturers concerned. But the total contribution to the nation's purchasing power which has resulted in this way must be very appreciable.

(Figs. 1 and 2 are reproduced by courtesy of the G.P.O. Engineer-in-Chief. Figs. 3, 5 and 6 are British official photographs, Crown Copyright reserved. Fig. 4 is a London News Agency photograph.)

The Migration of Butterflies

CARTWRIGHT TIMMS, F.R.E.S.

THE migration of butterflies has been observed for many hundreds of years, and there are many old records of the movements of vast swarms of these insects. Bird migration, of course, is a commonplace to the average observer, but many people are still unaware that our insect fauna is annually supplemented by visitors from overseas. That a lively interest is taken in this subject is proved by many queries, both in newspapers and on the radio, regarding the abnormal abundance of the humming bird hawk moth during 1947. Insect migration has long been known to entomologists, although it is only during fairly recent years that any attempt has been made to study the subject systematically. The matter was taken up by the South Eastern Union of Scientific Societies, which formed its Insect Immigration Committee,* and in 1931 Captain T. Dannreuther, R.N., organised an enthusiastic body of amateur entomologists, who send in regular reports from all parts of the British Isles. Additional records are received from lightships and lighthouses.

So today the arrival of any rare insect on our shores will almost certainly be seen and recorded, and, in the same way, any mass movement of the commoner species is also placed on record.

The Clouded Yellow

The older entomologists seemed to have little knowledge of butterfly migration and believed that many insects spend the winter in hibernation, when in fact they reach us only from overseas. Were it not for these annual arrivals, many species would disappear from the British lists. This seemed to be unknown to the early writers, who classed as hibernating butterflies several species, such as the Clouded Yellow (*Colias croceus*) that are unable to survive our unkind winters. Edward Newman, for instance, wrote that the Clouded Yellow is a hibernating butterfly, and that it "very frequently perishes before the spring; the survivors reappear in May and June". The spring butterflies, of course, are visitors from the Continent. There is no hibernating stage with the Clouded Yellow, for there is a succession of broods throughout the year, so that it is unsuited to the rigours of the English climate. The few butterflies that reach us in the early summer lay their eggs upon clover or lucerne. These eggs develop into butterflies in the autumn. Usually the butterflies appear in small numbers, but in some years the immigrants are so numerous that this charming insect appears in vast numbers. The Clouded Yellow has been unusually abundant during 1947, and many observers state that never before have so many been seen. The years of abundance have been called 'edusa years', for the old name of the butterfly was *Colias edusa*. It was in 1877 that the butterfly attained its greatest numbers, although this was challenged by the remarkable records of 1941. When all the reports are examined, it may be that 1947 will prove to be the best year yet for the immigration of the Clouded Yellow.

Records extending from 1825 to 1939 show that over this period of one hundred and fifteen years, there were only fifteen years when the Clouded Yellow was absent. During the other one hundred years, there were fifteen 'edusa years'. The invading butterflies lay their eggs in the South of England, but the resultant progeny flies northwards, and records in 1947 have been received from many parts of the country. The Clouded Yellow has been exceedingly plentiful in the Midlands, and has even penetrated into the parks and gardens of industrial towns.

A close relative of the Clouded Yellow is the Pale Clouded Yellow (*Colias hyale*) which has similar migratory behaviour. It is much rarer than the Clouded Yellow, and there have been few years in which it has been at all common, and many years in which it has entirely failed to appear. The long rainy winters in this country prevent the insect becoming established, although experiments have proved that the larvae are able to resist low temperatures.

Two of our most beautiful butterflies are unable to maintain themselves here without the aid of regular immigration from abroad. The Red Admiral (*Vanessa atalanta*) is frequently seen during the late summer, sunning its wings on the flowers of the buddleia and the Michaelmas daisy. Much controversy has raged about this butterfly. The older writers stated that it spent the winter in hibernation. Then it was stated to be a migrant and any suggestion of hibernation was repudiated. And now we have several authentic records that the Red Admiral does sometimes hibernate during the winter months. It is certain, however, that most of the Red Admirals seen in spring have reached us from abroad, although a few, perhaps, do succeed in finding shelter from the weather and surviving the winter's rages. This is one of the few butterflies that fly at night, and they have been known to visit the 'sugar' that the entomologist has prepared for night-flying moths.

A close relative to this insect is the Painted Lady (*Vanessa cardui*) which has similar habits. There is little reason to believe that this butterfly ever winters here, and it is safe to assume that all those seen in the early summer are migrants and are the parents of the many insects that are on the wing later in the year. In some years the autumnal butterflies are also increased by large migrations, so that the insect is unusually abundant. It has, in fact, been found in all parts of the country and in every month of the year, although there are few records of its appearance from December to February. A year of exceptional abundance was 1947, when the butterfly spread over a wide area. In some years the Painted Lady is comparatively rare and few butterflies reach our shores. It has, however, been recorded in varying numbers in every year since 1887. The proper home of the Painted Lady is North Africa.

It is curious that two of our most common butterflies, although having a high survival rate and finding no difficulty in maintaining themselves, are nonetheless

* Information regarding insect migration is welcomed by the Insect Immigration Committee. Reports should be sent to Captain T. Dannreuther, R.N., "Windycroft", Hastings, Sussex.

supplemented yearly by vast swarms from overseas. These are the Large White (*Pieris brassicae*) and the Small White (*Pieris rapae*), which are the only British butterflies that are serious pests, as every farmer and gardener is well aware.

Like a Snowstorm

It has been said that these insects travel in such numbers that the sky is darkened. This may be an exaggeration, but these butterflies have been seen by reliable observers in immense flights numbering many tens of thousands. A record from Saxony in July, 1937, speaks of a great swarm of Large Whites, ten kilometres broad, and from Switzerland in the same year a swarm was seen that looked like a great snowstorm. Similar flights have been witnessed at many points around the English coasts. The migratory habits of these butterflies were known to the early entomologists and there is an account of a flight of white butterflies reaching Dover on July 5, 1846. "There was a most extraordinary arrival of white butterflies," says the writer. "Every vessel that came into the harbour had the rigging and decks covered with them, and the pier was so thick in butterflies that you could not walk without treading on them."

In contrast to those butterflies that reach our shores in thousands, there are other migrants that are generally reported singly. These include some of our rarest butterflies, and the capture of a specimen is a great event for the entomologist. An instance of this is the Bath White (*Pontia daplidice*). This is a continental butterfly that usually reaches our shores every year, although it was entirely absent for one period of eight years. It was in 1945 that the Bath White made a surprise appearance in considerable numbers in the South of England. Their presence naturally attracted the attention of collectors, and one entomologist caught fifty-four at Falmouth during the month of July.

The grand prize of the collector is the Camberwell Beauty (*Nymphalis antiopa*) whose natural home is Scandinavia, where it is a fairly common insect. This butterfly is a late summer migrant, and there is no evidence that it has ever bred in this country. The adult insects hibernate, and a few manage to survive our winter and appear during the spring. It is more frequently found in the eastern part of the country, with records extending from Orkney to the South coast. The probability is that the migrations are from the East. It usually arrives in small numbers and in eighteen years was not recorded at all. Its year of greatest abundance was 1872 when four hundred and thirty-six were recorded.

The beautiful Swallow-tail (*Papilio machaon*) is occasionally reported from localities in the southern counties. Our native butterfly resides in the Fen District, where the caterpillar feeds on fennel and milk parsley. The migrant butterflies are different from our fen race, which is a distinct sub-species and cannot be confused with the continental type.

There are four other butterflies who visit our shores on rare occasions, and their appearance is welcomed by the collector and is usually recorded in the entomological journals. The lovely Queen of Spain Fritillary (*Argynnis lathonia*) is sometimes seen in the South of England and has even been known to breed here. During the eight years from 1902 to 1910 it was entirely absent.

Three species of 'blues' are among our rarest visitors. The Long-tailed Blue (*Lampides boeticus*), which has been recorded about thirty times, has been seen mainly in the South. Occasional specimens of the Mazarine Blue (*Cyaniris semiargus*) are observed, but only about one hundred have occurred during the past century. Rarer still is the Short-tailed Blue (*Everes argiades*) of which only seven records are known. There is, of course, the slight possibility that these blues may be here in large numbers, their superficial resemblance to the Common Blue causing them to be overlooked.

The most famous of our migrants, the Monarch (*Danaus plexippus*) is also the largest butterfly found in these islands. Its proper home is in Central America, tropical South America and the southern parts of the United States. Every spring there is a northward migration that extends into Canada, and in the autumn there is a return migration. Yet although it is a native of the Western Hemisphere, more than one hundred and fifty have been reported in this country. It is sometimes assumed, on account of the butterfly's migratory habits and its powerful flight, that it has flown the Atlantic, but there is little evidence in support of this belief. Unless the butterfly rested on the surface of the sea, it would have to fly continually both by day and by night. We may safely conclude, after a study of all available evidence, that the Monarchs found in this country have reached us as stowaways on ships. There are three well-defined geographical sub-species, and it is interesting to note that the majority of the specimens captured here have been of the North American type. The movements of the Monarch in America have been closely studied and a great wealth of material is available concerning one of the most migratory of all butterflies.

What is the cause of these vast insect migrations? We do not know. Over-population in a given area, with a reduction in food plant for the larvae so causing the females to seek new localities, is one explanation. It is not a complete explanation, for some species which migrate in the autumn do not pair until the spring, so any question of food shortage does not arise. Nor do we know how the butterflies find their way and maintain a fixed direction over several days or even weeks. Much study is being given to this difficult question, and it is thought that the most probable influences on direction are wind, light and the earth's magnetic field.

It seems certain that the stimulus behind migration is an exceedingly powerful one, for those years in which large-scale movements of one species occur, are also years when other foreign insects reach our shores. So entomologists speak of a good year or a bad year for migrants. What is more, the migratory urge is not confined to a limited area, for records clearly show that years of European abundance are paralleled by similar abundance in North America.

Much work still remains to be done on this subject, and the most humble observer is able to contribute his precious mite of information on one of the most puzzling, yet most fascinating of entomological problems.

Man against 'Worms'

GEOFFREY LAPAGE, M.D., M.Sc., F.Z.S.

THE animals which are called roundworms are among the most serious of the menaces which threaten human civilisation. Not only do they cause severe damage to some of our essential crops, such as wheat, oats, potato and sugar beet, but they also cause diseases of sheep, cattle and other farm stock, and some species of them cause crippling or fatal diseases of man himself.

It is impossible to estimate accurately the immense suffering and economic loss caused by these human diseases for which roundworms are responsible. Among them are hookworm disease and filariasis, which are discussed later in this article. Some idea of the damage done to our food supplies by roundworms can be obtained from the statement made by the National Veterinary Medical Association of Great Britain and Ireland that a single disease of sheep which is caused by roundworms, namely, inflammation of the stomach and intestines of these animals (parasitic gastro-enteritis) alone costs Britain at least £348,000 a year, a sum which is one-third of the total estimated cost of all the diseases of British sheep.

The roundworms are not so well known to the average man and woman as other kinds of worms are. Most of them are too small to be seen or studied easily and most people are no doubt unaware that they are among the most successful of all animals. They live in great numbers in a great variety of different situations—in the soil, in sewage, in fresh water and in the sea. Some thirty millions of them have been recovered from a single acre of soil in the United States. One species of them, the vinegar eelworm, lives in vinegar barrels and may sometimes be found in the vinegar in our cruets. The species which are parasitic also live in a great variety of situations inside the bodies of the animals in which they live; they can, in fact, be parasitic in almost every tissue in the animal body. The animals in which they are parasitic are called their '*hosts*' and very often particular species of roundworms can live only in certain species of host animals.

A roundworm is cylindrical in shape and pointed at both ends. The surface of its body is not marked with rings as the surface of the body of an earthworm is; it is smooth and glistening, this appearance being given to it by the peculiar kind of skin which it has. The bodies of small roundworms are transparent or semi-transparent, so that many of the internal organs can be seen through the skin; but the skin of larger species is thicker, so that these species are opaque and they have an appearance which has been compared to that of wet porcelain. A roundworm is built of two tubes, an inner one, the food canal, inside the other, the body wall and between these two tubes is a space which contains fluid under pressure, in which the long coils of the voluminous reproductive organs lie. The sexes are in separate individuals and the male is always smaller than the female.

Complex Life Histories

Most of the methods by means of which we seek to control the damage done by roundworms are based upon our detailed knowledge of their life histories, so that it will help us if some of these life histories are now briefly described.

First let us look at the life history of one of the roundworms which cause the inflammation of the food canal of sheep and cattle mentioned at the beginning of this article. This species lives in the true stomach of these animals (the abomasum) and it is often called the large stomach worm of the sheep. Its scientific name is *Haemonchus contortus*. Fig. 1 illustrates the plan of the life history of this species.

The adult worm lives in the true stomach and there lays eggs which are passed out of the host in its droppings. These droppings act, under normal conditions, like miniature incubators which provide warmth and protection for the first-stage larvae which hatch out of the eggs and also plenty of bacteria on which these larvae feed. The first-stage larva grows and moults its skin so that a second-stage larva is formed which also grows and moults its skin, thus becoming the third-stage larva.

This third-stage larva cannot, however, develop further on the pastures. It retains around itself the cast skin of the second-stage larva and awaits an opportunity to enter the host and become parasitic. If it cannot find a host, it eventually dies. Only this third-stage larva can infect the host. For this reason it is called the *infective larva*.

The activities of infective larvae of nematodes are largely governed by responses which they make to chemical and physical stimuli in their environment. If, for example, they are buried in the soil, they move upwards, against gravity, to the surface. They also move away from bright light and tend to collect in regions in which the light is of medium intensity. If they come into contact with solid or semi-solid surfaces, they keep their front ends in contact with these surfaces and seem to try to bore into them. The fact that the infective larvae of many species do bore into animal tissues is, as we shall presently see, important.

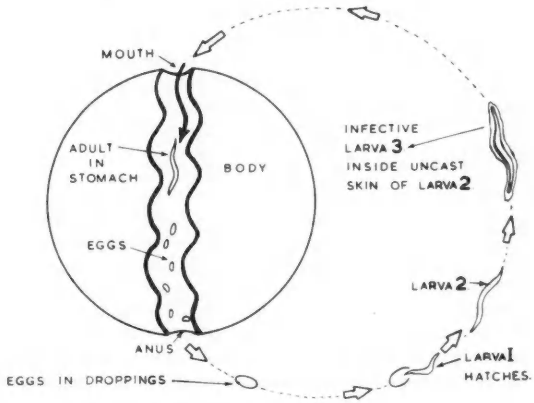


FIG. 1.—Life history of sheep stomach worm.

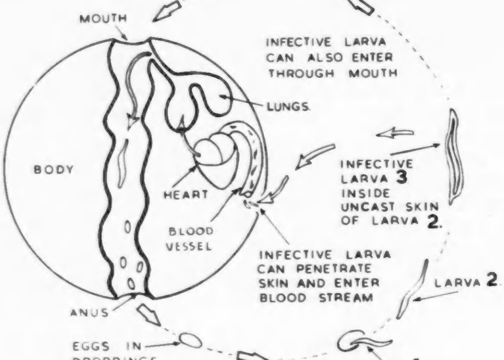


FIG. 2.—Life history of human hookworm.

The net result of the responses of this kind which the infective larvae of the sheep stomach worm make to stimuli in their environment on the pastures is that they migrate up the surfaces of the leaves of pasture plants. This they do especially when these leaves are wet with rain or dew and when the light is of medium intensity in the early morning or at dusk. Sheep and other animals grazing will therefore readily eat many of these infective larvae, so that they infect themselves with the stomach worm. The infective larvae, when they are swallowed by the host, are set free from the old skins of the second-stage larvae and become parasitic. They cause bleeding in the wall of the stomach of the host and they live and grow under the blood clots which are thus formed. In about three weeks they are mature and the life cycle is complete.

Three general features of this kind of life history may be noted before any other life histories are considered.

First, each egg gives rise to one individual roundworm only. Roundworms cannot, that is to say, multiply the number of individuals derived from each egg, as the flukes, tapeworms, the malarial parasites and some other parasitic animals can.

Second, the life history of the stomach worms is divided into a parasitic and non-parasitic phase. The first three larval stages are not parasitic. *Haemonchus contortus* is a type of parasitic animal which spends the earlier part of its life history in the external world outside the host.

Third, the host can be infected only by swallowing the infective larvae.

The Hookworm

An alternative method of infection of the host used by some species of roundworms is illustrated by the next life history to be considered, namely, that of the human hookworm (*Ancylostoma duodenale*). Fig. 2 illustrates the plan of this life history.

The human hookworms live, not in the stomach of man, but in the part of the intestine which immediately succeeds it, the duodenum. Like the sheep stomach worm, the human hookworm lays eggs which are passed out of man in his excreta. From these eggs first-stage larvae hatch out and these, like the first-stage larvae of the sheep stomach worm, grow and moult their skins and become second-stage larvae which in turn moult and become third-stage or infective larvae enclosed in sheaths, which are the cast skins of the second-stage larvae.

All this part of the life history is non-parasitic and occurs either in human excreta or in moist, warm soil. The infective larvae of the hookworms can, like those of the sheep stomach worm, enter man by the mouth with his food or drink; but they have also developed another way of entry—they can bore their way through his skin, and this is the way by which they usually enter the human body. It is a mode of entry which obviously increases the roundworm's chances of entering the host. It carries with it, however, a difficulty—the larvae, after they have thus entered man through his skin, find themselves, not in the food canal in which they mature, but in the spaces filled with lymph underneath the skin. How do they get from this situation to the food canal? They enter the small blood vessels (capillaries) under the skin and are carried by the blood to the heart, by which they are pumped to the lungs with the blood which is going to these organs to be aerated. Some of them are carried with the blood through the lungs to other organs of the body and these will die; but most of them remain in the small blood vessels in the lungs, where they grow to a stage which breaks its way out of the blood vessels into the air spaces of the lungs. From these air spaces the larvae wriggle into the smallest air tubes and from these they progress up to the windpipe. Reaching the point at the back of the throat where the windpipe opens, they pass over into the gullet and get down this to the stomach and so to the duodenum, in which they mature. Usually hookworms will be laying eggs in the duodenum some five weeks after their infective larvae have bored their way through the skin of man.

A third kind of roundworm life history is that of *Ascaris lumbricoides*, sometimes called the large roundworm of the pig and man. The life history of this species is illustrated by Fig. 3. It is similar to that of the stomach worm and the hookworm, but the first-, second- and third-stage larvae develop inside the eggs instead of in the world outside the host. These larvae are, therefore, protected inside the egg.

The infective larva cannot, therefore, infect the new host by its own efforts. It must depend upon the swallowing of the egg and the infective larva inside it by the new host. This life history is thus an example of infection by contamination of the food or drink by a passive *infective egg*. We should, perhaps, naturally expect that the infective larvae of this species, when they are freed from the swallowed egg by the digestive juices of the new host, would grow up in the alimentary canal in which they then find themselves and in which the adult worm normally lives. We find, however, that they do not do this. First, they exercise a tissue-penetrating habit similar to that of the skin-penetrating hookworm larvae. They bore through the tissues around them, namely, the walls of the alimentary canal, so reaching blood and lymphatic vessels of the intestinal wall. All the blood in these vessels must go to the liver, so that the infective larvae of *Ascaris* are also carried to the liver where they can cause considerable damage. Thence they are carried to the heart, to join the route taken by the larvae of hookworms. An important part of

their development takes place in the lungs, where their presence may cause serious symptoms. Breaking their way out of the lung, they wriggle up the air tubes, pass down the gullet and become mature in the small intestine in which their infective larvae began their journey.

The fact that the first-, second- and third-stage larvae of *Ascaris* do not live in the world outside the host, but are protected inside the egg, is interesting. Entry into the world outside the host carries with it serious risks. Countless eggs and non-parasitic larvae which thus leave the host are killed by drought, cold and other climatic agencies or are eaten as food by other animals. Many parasitic animals, like many non-parasitic ones, counter the effects of this inevitable destruction by producing very large numbers of eggs and for this reason their reproductive organs are often very voluminous. But we find, among parasitic animals, other methods of countering the risk of destruction of the defenceless larval stages. *Ascaris* protects them inside the egg shell. Two other methods of protecting them which are used by roundworms can be illustrated by the other life histories to be considered.

Trichiniasis

(1) The parasite may retain its infective larvae inside the host. It can then infect new hosts only when these new hosts eat the host in which the infective larvae are produced. This is the method adopted by *Trichinella spiralis*, sometimes called the pork Trichina worm, a nematode which causes a serious disease of man and other animals (Fig. 4). *Trichinella spiralis* is a small nematode which lives in the small intestine of man, pigs, dogs, cats, foxes, bears and other mammals. The females are viviparous; that is to say they lay, not eggs, but living larvae. This fact is in harmony with the complete committal of this species to parasitic life. When these larvae are set free in the small intestine, they bore their way through the intestinal wall into the blood channels there and are carried by the blood all over the body. They settle, however, in the voluntary muscles and especially in the midriff and in the muscles of the jaws and the ribs. These muscles react to their presence by forming around each larva a cyst inside

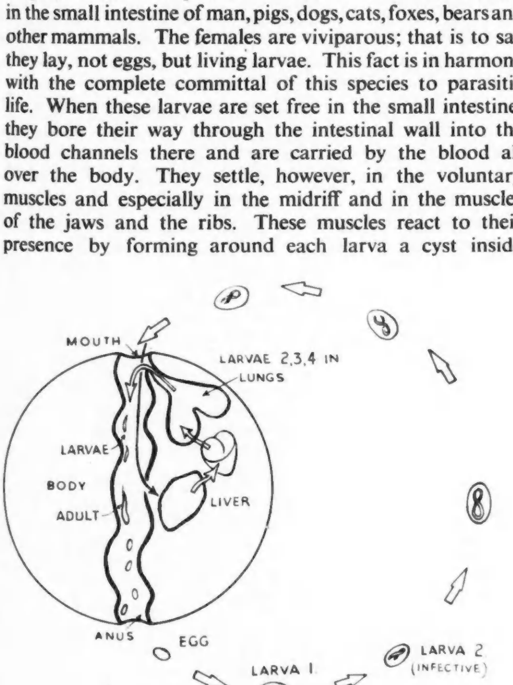


FIG. 3.—Life history of *Ascaris lumbricoides*.

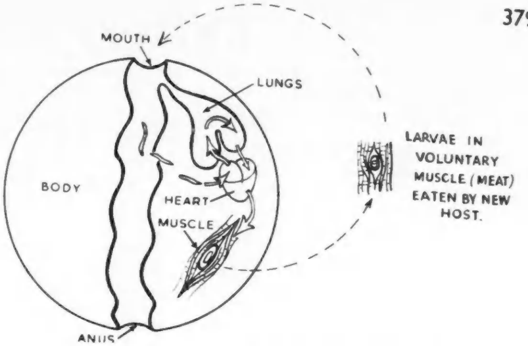


FIG. 4.—Life history of *Trichinella spiralis*.

which the larva grows. If the host into whose muscles these larvae have penetrated is not eaten by another susceptible host, chalky material is eventually deposited in the cyst and the larvae die. This calcification of the cysts begins about six to nine months after the larvae have arrived in the muscles.

If, however, the flesh of the infected host is eaten by another susceptible host the larvae resist digestion by the latter and grow up in its small intestine into sexually mature Trichinellae, which in their turn produce larvae which infect this new host's muscles.

It will be clear, therefore, that Trichinellae which arrive in the muscles of human beings are doomed (unless human cannibalism occurs) to die there in cysts which are eventually calcified. How then does man become infected if he no longer eats other men? Normally he is infected by eating the raw or imperfectly cooked flesh of the pig which is infected with the larvae of Trichinellae. Infected bear meat was the cause of one large outbreak of trichiniasis at Stuttgart in Germany. Other animals whose muscles may be infected are the wild boar, the dog, the cat, the fox, the mongoose and possibly the badger. Chickens are rarely infected. All these animals can infect themselves by eating each other; but it is probable that they are chiefly infected by eating the infected muscles of the brown and black rat, which are the main propagators of the parasite. Rats and also their dead carcasses should therefore be kept away from pigs and pigs should not be fed upon uncooked garbage. In Syria, just after the departure of the Vichy French, an outbreak of Trichiniasis in man occurred and it was found that one of the main piggeries was situated (at Beyrouth) near to a town refuse dump and that the pigs were being fed upon refuse which often contained carcasses of dead infected rats.

Other methods of control of trichiniasis are inspection of pork by methods which enable the larvae encysted in the muscles to be detected before the pork is issued for consumption and, more important and much simpler than this, the efficient cooking of pork and the abolition of the habit of eating raw pork. Trichiniasis is rare in Britain, but investigation of one outbreak in England in 1940–1 showed that the habit of eating raw pork, especially in the form of sausage meat, is much more widespread than has been supposed. That particular outbreak was largely due to the habit of factory workers, especially girls, of taking uncooked sausage meat in their sandwiches for lunch, because they had no time to make up each night a lunch of cooked meat.

[To be concluded.

Letters to the Editor

SALARIES OF SCIENCE TEACHERS

SIR—I have become so used to the excellence of *Discovery* and to a feeling of warm approval of its editorial attitude on matters concerning science and social policy that it is almost with surprise that I find something with which to disagree. I do not dispute the need for adequate pay for graduates, but it is exceedingly serious if we try to support a reasonable demand with arguments that, if accepted, would put educational progress into reverse. You quote (September 1947, pp. 257–8) with approval the statement that the key to the whole of higher education lies in the teaching of the higher forms in schools, particularly sixth forms, and later state that the quality of the men who do our sixth-form teaching is the keystone of our whole educational system. If this is a fact it is one that enlightened educators have for years deplored, and is therefore a dangerous argument for attracting graduates into the profession. As the expression of an attitude or an assessment of values, it fails to recognise that many evils necessarily follow from it. The emphasis on the significance of sixth-form work, which concerns only a small proportion of even the Grammar School population, and the special honour given to first-class graduates concentrating on advanced work, have bolstered up the narrow academicism and specialisation whose evil effects have begun seriously to show. Readers will be aware of the disturbance that is increasingly felt about the quality of Higher Certificate and scholarship pupils, arising not from their lack of specialised training, but from the excess of it and from the lack of general quality and culture. Sixth-form work, in spite of all the glamour that attaches to it, is in fact dominated by motives and requirements that are chiefly economic and have little to do with education. Because of the false significance we give to it the effect is felt throughout the school.

From statements made to me by several university teachers, it seems that the effect is not only to impair the quality of students as human beings but also as scientists. These lack the imagination, wide awareness and quick response upon which originality in science so largely depends. The growth of these mental qualities depends upon educational conditions years before the sixth-form stage. As a reasonably experienced science teacher I would say that a young honours graduate from a University, keen on his subject, can romp away happily with a sixth form and achieve good paper results without much investigation of educational problems. To know what has to happen in the mind of a thirteen-year-old, so that his scientific knowledge becomes part of his equipment as a democratic citizen, or even to make sure that he becomes a *good* scientist, requires a mature understanding and a long discipline of investigation. It is by no means always the sixth-form teacher, caught in the web of specialisation, who undertakes this exacting work or achieves the knowledge.

In our national administration we have been moving towards the recognition that from the point of view of the survival of democracy the education of the ordinary man requires as much attention and deserves as much honour as the education of the intellectual élite. To realise this in practice is exceedingly difficult and mistakes in policy are inevitable. But when we seek to remedy these mistakes let us beware of merely turning back to the status quo and destroying the good that is trying to emerge. We need first-class minds throughout the *whole extent* of education, and as an argument for higher pay we need say no more than this: that while we recognise the incalculable services to education of those who make it their vocation, in the profession as a whole we shall get what we need only if we are prepared to pay for it.—Yours, etc.

KENNETH C. BARNES,
Wennington School,
Wetherby, Yorks.

THE EFFICIENCY OF GAS AND ELECTRICITY

SIR—In his article on "Britain's Fuel Problems", published in your June 1947 issue, Dr. G. E. Foxwell compares an 'efficiency' of 50% for a "balanced set of gas and coke appliances" with an 'efficiency' of 15% for electricity, and comes to the conclusion that the policy for all new houses should be to use coke (or smokeless coal) and gas, wherever it is available, for all space-heating, cooking, water-heating, and refrigeration purposes.

The method of comparing efficiencies Dr. Foxwell uses is fallacious. This has repeatedly been pointed out, most recently in a paper entitled 'Comparisons between Gas and Electricity on the Basis of Coal Economy', read by me before the Institution of Electrical Engineers, and proving that "with present processes of electricity and gas production and utilisation, no decided difference with regard to coal economy exists between gas and electricity for domestic heating purposes."

A simple proof is this:

The carbonisation of 20 cwt. of gas coal leaves a residue of coke and breeze of 9 cwt., whose calorific value is more than 10% lower. This modified solid fuel is, therefore, equivalent to 8 cwt. of the original coal, and 12 cwt. of the latter may be considered as used in the process, which yields 75 therms of gas, and some liquid by-products.

In order to make a correct comparison with electricity, one has to adopt ratios between gas and electricity consumptions for equivalent services. The Report of the Heating and Ventilation (Reconstruction) Committee of the Building Research Board uses 1 therm of gas = 14 kWh of electricity for cooking, and 1 therm = 11 kWh for space-heating. Hence, to provide the equivalent of 75 therms of gas, it is necessary to apply 1050 or 825 kWh of electricity, depending on whether the gas is used for cooking or heating. With an average actual coal consumption of 1·7 lb. per kWh of electricity sold, it requires 16 cwt. of power-station coal to supply 1050 kWh, and 12 cwt. to supply 825 kWh. Considering the substantially lower calorific value of such coal, these amounts are equivalent to 13½ cwt. and 10 cwt., respectively, of gas coal—as against the 12 cwt. used in the gas-works process.

A number of minor adjustments can be applied to this rough calculation; for instance, by allowing for the somewhat improved working efficiency of certain solid-fuel appliances achievable if coke is used instead of coal; but the substance of the proof remains unaffected.—Yours, etc., P. SCHILLER.

Dr. Foxwell has sent the following reply to Mr. Schiller's comments:

MR. SCHILLER is drawing an unnecessary red herring across the trail of fuel efficiency by introducing the partisan argument of gas versus electricity. The purpose of my article was to point out that our coal reserves are as limited as our ability to mine them and that every possible means should be taken both to conserve those reserves and to make the annual amount of coal mined go farther by using all fuel to the best advantage. To that end I have recommended in my article a large extension of electricity for power purposes including railways. There are purposes for which each type of energy available to us is better suited than other types and it is my contention that each should be used to the best advantage, due regard being paid to efficiency, economics and the need for conserving coal. Nationalisation of the fuel industries should cut out the purely 'commercial' competition between them and allow policy to be based on technical facts.

I am surprised that Mr. Schiller should draw the attention of your readers to his paper. I was present at the meeting to which he referred and heard the devastating criticisms of it voiced by Dr. Oscar Faber and others of my colleagues of the profession of fuel technology. Dr. Faber on that occasion summarised the position by pointing out that, argue as we may, the fact remains that it requires at least twice as much coal to provide a given amount of useful heat for domestic purposes by electricity as by the combination of gas and coke which is supplied by the gas industry.

It is of interest to look at Mr. Schiller's own figures. He indicates that 825 kWh are produced from 12 cwt. of coal, i.e. 1 ton of power station coal generates 1370 kWh. We then have

Potential heat in 1 ton of power station coal = 240 therms
Potential heat in 1370 kWh (1 kWh = 3413 B.Th.U.) = 47 therms
Thermal efficiency = $47 \times 100/240 = 19\frac{1}{2}\%$.

This assumes that the current is delivered without losses and is used at 100% efficiency. Electricity is used for many

purposes in the house and its overall efficiency is certainly less than 100%. Thus from Mr. Schiller's own figures the overall efficiency of electricity in the house, from coal to useful heat, is seen to be of the order of 15%, which is the figure I gave. No amount of specious argument can conceal the fact, therefore, that the use of electricity for generating heat for domestic purposes is identical with that of the open coal fire which is so roundly condemned by all authorities for its wasteful use of coal.

Coal carbonisation, by comparison, is conducted with some 20% heat consumption and the coke and gas so secured are used in modern appliances with an efficiency of 40 to 75% according to circumstances—an overall efficiency of 32 to 60%. Dr. Faber gave the overall efficiency of gas and coke for domestic heating as 50%, and if this figure be accepted the efficiency of the carbonising industry from coal to useful heat is 40%.

Finally, may I clarify the position as regards district heating. It can be shown that the use of the products of combustion, taking into account the consumption of heat in the carbonising process, is superior in thermal efficiency to an independent coal-fired district heating installation. When, however, the hot water required for the district heating system is heated by the back-pressure steam from power-station turbines, the district heating system is superior. There are certain practical difficulties in doing this (cf. Prof. Kapp, *Journal of the Institute of Fuel*, Vol. 19, p. 77) and it must be confessed that the electricity supply industry in Britain appears to have shown no enthusiasm for the idea.

International History of Science Congress

MY most vivid recollection of the 5th International Congress of the History of Science, held at Lausanne from September 30th to October 6th, will always be a lecture by Professor Elie Gagnebin on the history of geological theories of the Alps. What wonderful conditions he had to deliver it in! It was the last day of the Congress, a day not of lecture rooms and blackboards but of a sightseeing excursion, farewell meals and speeches of thanks and congratulations. The excursion included a rack-railway ascent of the Rochers de Naye (6710 feet) above Montreux at the east end of the Lake of Geneva. From there we looked down on the Lake and on the Rhone Valley, or across the Lake to the Dents du Midi, or eastwards to the Jungfrau and the mountains of the Bernese Oberland. A warm sun poured down on us and visibility was well-nigh perfect. And standing on the very summit Professor Gagnebin gave his lecture. As he told us of the various stages of the building-up of the Alps, he was able to point to the reality all around—to the various routes taken at different periods by the Rhone, to the clear evidence of the power of erosion contained in the distinctly visible suspension of mud carried down by the Rhone and spreading well out into the Lake before settling, to the quite clearly defined slope cut by the massive glacier which covered all Switzerland in the ice age, to the different shapes of mountains arising from different geological structures, and so on. With the subject matter in front of us, Professor Gagnebin was able to make abundantly clear the stages by which the workers of a couple of centuries elucidated the problem of the history of the Alps.

War caused hiatus

As an organised study the history of science was probably harder hit by the war than any of the scientific disciplines themselves. In other subjects, military applications ensured that at least some of the branches were intensely studied between 1939 and 1945, while some form of United Nations liaison partly replaced the international organisation of pre-war days. In the history of science, on the contrary, the amount of research was very much reduced, and the International Academy of the History of Science had to be put into cold storage for the whole war period—worse still, almost all its records and papers were destroyed, so that continuity could only be maintained through the memories of its members.

Augury for future

In these circumstances it was quite a triumph to hold even a modest international congress. The Lausanne Congress could be called no more than modest—there were some fifty congress members, representing about a dozen countries in Europe, North and South America and the Near East—but within its limitations it was a success. And there was a spirit of optimism that augurs well for the future.

About thirty papers were read to the Congress. Naturally many of them were concerned with solving detailed problems, intensely interesting to the specialist. As they will all be published in the report of the Congress, I can be excused for mentioning only two which were of more general interest. Professor P. Sergescu of Roumania gave the Congress an excellent send-off with a paper on the rapid development in mathematical thought at the beginning of the nineteenth century. He showed clearly the close connexion between apparently abstract mathematical matters and the social events of the times—the new spirit of the French Revolution and the intellectual ferment that preceded it, the technical needs of the revolutionary and Napoleonic wars, the new educational institutions set up by the revolutionary government, and so on.

Dr. Charles Singer of this country gave an account of his recent researches on Vesalius (now available in book form), which greatly clarified the role of Vesalius in the beginning of modern science and showed it to be even more important than has hitherto been believed.

On the organisational side, those members of the International Academy of the History of Science who were present took the opportunity to set that body on its feet again.

International Union formed

The Academy, however, is a self-perpetuating society of scholars, elected on the basis of their scholarship; it is not an international representative organisation. For that reason it is not an ideal body for the international co-ordination and promotion of research in the history of science. In order to provide organisation which could do these things and which would fit more easily into the general scheme of international science organisations, the Academy had agreed with Unesco on the formation of a new body—the International Union of the History of Science. This has a constitution similar to the international unions of the various branches of science. Its members consist of (*a*) members of the Academy and (*b*) elected national representatives. It is affiliated to the International Council of Scientific Unions and through the latter it is in close touch with Unesco.

During the Congress the International Union held its first assembly, elected its officers, approved an outline budget and sketched a plan of work. The officers elected were: *President*, Dr. C. Singer (Gt. Britain); *Vice-Presidents*, Professor A. Reymond (Switzerland) and Prof. G. Sarton (U.S.A.); *General Secretary*, Prof. A. Mieli, in whose absence Prof. P. Brunet (France) will deputise; *Executive Secretary*, Prof. P. Sergescu (Roumania); *Treasurer*, Mons. J. A. Vollgraff (Holland); *Assessors*, Mons. J. Pelsenner (Belgium) and Dr. S. Lilley (Gt. Britain).

Three commissions were appointed to carry out activities in particular fields, namely: (1) the teaching of the history of science, (2) the cataloguing of manuscripts, and (3) the history of the social relations of science. The budget for 1948 amounts to $14,000, of which $10,000 comes from Unesco. Apart from administrative expenses, the main expenditure at present envisaged will be on publications.

S. LILLEY.

The Bookshelf

What is Atomic Energy? By Dr. K. Mendelssohn. (Sigma Books, London, 1947; pp. 180, 12 plates; line drawings by V. Reinganum.)

THE title 'Atomic Energy' nowadays covers a multitude of subjects and this particular book is concerned mostly with an attempt to explain to the non-specialist reader the basic ideas of modern atomic and nuclear physics. Dr. Mendelssohn says in the introduction that he has set himself an ambitious task and in reading through the book one wonders whether he is not being a little too ambitious. The real meat in the book is in Chapters IV to VII which endeavour to bring out the ideas of modern theoretical physics. To deal with our knowledge of the behaviour of particles with quantum theory as well as relativity in about 65 pages is an enormous undertaking, and the author is to be congratulated on conveying in that space even a little of the atmosphere. In avoiding technicalities the language has to be general and in places it tends to become a little vague. One would have liked to see a little more of the actual reasoning of the physicist illustrated, at least in some simple cases, so as to dispel the almost mystical awe with which the work of the mathematical physicist is often regarded by the experimentalist as well as by the layman.

Dr. Mendelssohn's book tends to confirm the impression that the mathematician produces results by some mysterious process of calculation which cannot be appreciated by the non-expert. The account given in these chapters does not always follow the actual development; for instance, the order of the theoretical and experimental work on electron diffraction is reversed and the discoveries which brilliantly confirmed the ideas which theoretical work had derived from other basic facts are presented as surprise discoveries which were explained only later. Similarly, the statistical interpretation of quantum theory was put forward by Born and others in the very early stages of the development, and did not form, as the book presents it, a crowning piece put afterwards on an otherwise complete structure. The electron microscope owes nothing to wave mechanics but the knowledge of its limitations.

In the other chapters, too, the desire to keep the language simple has often led to vague statements where precise statements would have been as easy to make and easier to understand, and quantitative statements are often made in a form which makes them appear much more accurate than they claim to be. For instance, the statement that a 1 Kw hour can make 65 kettles boil is not only wrong, but also attempts to be needlessly precise in view of the vagueness of what exactly is meant by 'one kettle'.

The chapter on the Atomic Energy Project follows fairly closely the various official accounts: here, as in the rest of the book, the very amusing drawings liven up the story and help to make its meaning clear.

In spite of some complaints the book is very readable and thought-provoking and will give many readers the desire to go more thoroughly into the questions that are touched upon. It is likely to be read widely and if, as I hope, it will run to several editions, there may be an opportunity of correcting the many typographical errors and minor slips that strike the eye, including one which has crept into the list of errata. R. E. P.

Science in Transition. By A. W. Haslett. (Christopher Johnson, London, 1947; pp. 244, 10*s.* 6*d.*)

THE bulk of this timely little book, written by the editor of *Science Today*, deals with certain branches of applied science in which important developments have recently occurred, most of them during the war. Pride of place is given to the release of nuclear energy. The author traces the steps which led with seeming inevitability from the invention of Sprengel's air pump in 1870 to the construction of the first atomic pile in 1944, following this with a chapter on artificial radioactive elements and their medical applications and with a further chapter on the future of atomic energy in which such matters as atomic power plants and international control are discussed.

The second section deals with radar of which Mr. Haslett writes with the authority of personal experience gained as a radar officer. The history of radar development is lucidly described, a further chapter dealing with the application of radar and radar principles to navigation, computation, meteorology and surveying. The author then turns his attention to problems of nutrition and shows that known scientific principles, if intelligently applied, can go far to relieve the chronic malnutrition which exists in so many parts of the world. A discussion of the correlation between malnutrition and the incidence of disease leads naturally to a chapter on chemotherapy. The final descriptive chapter is on jet propulsion and includes an excellent review of Whittle's work.

It will no doubt seem to many that such things as the atom bomb, the atomic pile, radar, DDT, penicillin, V-weapons and the Gloster Meteor are concrete proof that war provides a tremendous impetus to the advancement of science. Mr. Haslett sets out to show that this is not so, using these same examples to support his argument. All these, he says, are the products of applied science and technology: the pure science which made them possible was in each case worked out before the war. Pure science is a long-term investment and one can never be sure when and in what form its dividends will be paid. In war-time pure science goes to the wall—a state of affairs which, if allowed to continue, will inevitably retard technological advance in the future.

Owing to the nationalisation of heavy industries and to the enormous cost of research apparatus in several important fields, Mr. Haslett points out that the state will be called upon to subsidise pure research to an ever-increasing extent. This raises such controversial issues as the direction of research by the state, the provision of facilities for training an increasing number of scientists, the education of the public in general scientific principles, and the responsibility of the individual scientist for the social consequences of his work. On these matters Mr. Haslett is original and stimulating, whether or not one agrees with what he says.

It is a pity that one has to record one or two minor errors. The thyroid is spoken of as a 'gland at the back of the neck' and there seems to be some misunderstanding of the principles of the Campini jet aircraft to which the author refers indirectly. But in a book which covers so wide a field and which is at the same time so topical, immaculacy in this respect would be something of a miracle. R. P. H.

The Principles and Practice of Wave Guides. By L. G. H. Huxley. (Cambridge University Press, London, 1947; pp. 325, 21*s.*)

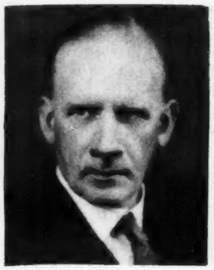
IT has been known for some fifty years that it is theoretically possible to guide radio waves through a hollow metal tube, but only with the war-time development of centimetric waves did this become a practical possibility. Not only is it practical, but it is in fact the best available technique for these very short waves.

Dr. Huxley's book combines an exposition of the principles underlying waveguide transmission with a description of the wave-guide techniques which have been developed in connexion with radar.

The first three chapters are devoted to the principles of the subject, using simple mathematics and easily pictured ideas. Chapter IV is a useful compendium of essential wave-guide techniques. In Chapter V Dr. Huxley shows in considerable detail how the impedance concept can assist the engineer engaged on development work, particularly as regards the properties of obstacles, bends and junctions. Apart from a few illuminating remarks, he has wisely refrained from straying into the neighbouring field of aerials.

Electromagnetic cavity resonators are closely related to wave-guides, and their many applications make the chapter on them welcome. A final chapter on various selected topics will appeal chiefly to specialists.

The book is attractively printed, with copious diagrams, and, except in the final chapter, no more mathematical knowledge is required of the reader than may be expected of the average radio amateur. Misprints are few. The only criticism one might level is that it shows too plainly its origin from lecture notes, and gives undue emphasis to techniques developed at the Telecommunications Research Establishment, where the lectures were given. M. H. L. PRYCE.



Sir Robert Robinson

Sir Edward Appleton

Prof. Carl Cori

Dr. Gerty Cori

Prof. Bernardo Houssay

Far and Near

The Nobel Prizewinners

THE 1947 Nobel Prizes for physics and chemistry have both gone to British scientists, the physics prize being awarded to Sir Edward Appleton, F.R.S., "for his work on atmospherical physics and especially for his discovery of the Appleton layer", and the chemistry prize being awarded to Sir Robert Robinson, P.R.S., "for his researches on important substances in plant biology, especially alkaloids".

It was in 1924 that Appleton, who has been secretary of the Department of Scientific and Industrial Research since 1939, devised a method by which could be proved the existence of a layer in the upper atmosphere which reflected radio waves and by which the height of this layer could be measured.

The principle of the method was that if radio waves of a definite length were sent out from a station, two sets of waves should be picked up on the receiver. One set of waves should travel along the ground and the other should be reflected back to the ground from the supposed layer in the atmosphere. If the two sets of waves arrived in step, they would reinforce each other and give a strong signal. If, on the other hand, by slightly changing the wavelength, the sets of waves arrived out of step, they would cancel each other out and give a weak signal. If the two stations were fixed and the wavelength was changed continuously, the signals received would wax and wane in strength, and artificial fading would have been achieved. By counting the number of fades caused by a given change of wavelength it would be possible to calculate the distance by which the reflected path exceeded the ground path. Then by simple geometry the height of the reflecting layer could be calculated. The experiment carried out by Appleton and Dr. M. A. F. Barnett, using the B.B.C. transmitter at Bournemouth and a receiving station at Oxford, worked according to plan. By 12.15 a.m. on December 11, 1924, Appleton had not only proved that a reflecting layer did exist, but that its height above the earth was 60 miles. The existence of Kennelly-Heaviside or E Layer had been established.

This first experiment was done with medium wavelengths. Appleton later proved that shorter wavelengths (10 to 50 metres) penetrated the Heaviside Layer and yet were reflected back to earth from higher up. This was the discovery of what is called the Appleton or F Layer, 120 miles above the ground.

Sir Robert Robinson, who has been President of the Royal Society for the past two years, established his reputation as a great organic chemist with his synthesis of tropinone, an alkaloid with a ring structure, from the straight chain compounds succindialdehyde, acetone and methylamine. Shortly before he attempted that synthesis he had worked out a theory to explain how plants might build up chemical products. It was that theory which led him to his tropinone synthesis, and fifteen years later it was proved that the particular sequence of reactions that went to this synthesis did actually occur in the living plant.

From the alkaloids (his researches included work on morphine and he also established the structural formulae of strychnine and brucine), he turned to a study of flower pigments. His successful synthesis of the blue-red pigments (anthocyanins) has been described as "one of the most brilliant achievements in the whole range of modern organic chemistry".

More recently Robinson collaborated with Professor E. C. Dodds in a study of sex hormones and the outcome was the synthesis of three substances—stilboestrol, hexoestrol and dienoestrol—which are chemically not identical with any natural hormone but which are physiologically more active than the oestrogens so far discovered. A fuller account of Sir Robert Robinson's work was published in DISCOVERY in January 1946 (Vol. 7, pp. 7–8).

The Nobel Prize for medicine and physiology has been awarded jointly to Professor Bernardo A. Houssay, and Professor Carl F. Cori and Dr. Gerty T. Cori, who are all distinguished for their investigations on carbohydrate metabolism, a subject extremely important both for its fundamental nature and connexion with diabetes.

Professor Houssay has done brilliant experimental work on the regulation of blood sugar by hormones secreted by the pituitary, pancreas, thyroid and adrenals, making extensive use of animals deprived surgically of one or more of these glands. An animal with both pancreas and anterior lobe of the pituitary removed is widely known as a 'Houssay animal'. Dr. Houssay, an Argentine, is the first South American scientist to win a Nobel Prize. He was until recently professor of physiology in Buenos Aires University, being relieved of this post by the Perón regime.

The Coris have made important contributions to the elucidation of the complex series of steps whereby living matter ferments starch to alcohol or converts glycogen to lactic acid in muscle. The Coris were born in what used to be Austria-Hungary. They both were students and began research at Prague University. They have worked at the Washington University School of Medicine since 1931.

New Steel Research Laboratory

THE two most substantial research projects which are being undertaken in the recently opened physical laboratories of the British Iron and Steel Research Association at Battersea are an investigation of the physical problems involved in the continuous casting of steel, and the study of flame and gas flow in furnaces. As the research staff of the physics department has been built up progressively over a period, and with university facilities temporarily available, the new laboratories were already a working organisation by the date—October 22—that they were officially opened by Lord Rayleigh.

Factors involved in the continuous casting investigation are the rate of loss of heat by the steel from conduction through the mould, the extent to which the continuously cooling metal separates from different designs of mould and the

physical properties of steel during solidification. The equipment designed for the first involves a simple and sensitive form of cathode-ray-tube display, and on the wider question of physical properties it is hoped to obtain useful information from rheological models.

The problem of gas flow in furnaces is essentially an aerodynamics problem, and the familiar technique of the scale model is accordingly being applied. In one use of models, small quantities of carbon dioxide mixed with air are introduced through what would normally be the gas port of a transparent model of an open-hearth furnace, and samples removed through an adjustable probe for carbon dioxide analysis by the infra-red method. The technique has been shown capable of providing a continuous series of 'contour lines' indicating the extent to which the injected gas reaches all parts of the model. Comparison with full-scale conditions is greatly facilitated, by contrast with aircraft research, by the availability of an extensive collection of film records showing the flow-patterns under varying conditions in industrial furnaces. This means that, by the use of smoke colouration in the model, an empirical check on the validity of scale deductions can be simply made.

A considerable amount of work has also been done, in advance of the official opening of the laboratory, on the design and testing of instruments for various purposes. An example is the experimental pyrometer, using a lead-sulphide cell of the type developed during the war by the Admiralty, for the measurement of temperatures in the range 150–600 degrees Centigrade, as shown earlier this year at the Physical Society's Exhibition. A second new instrument, already at a practical stage, applies the technique of the valve-maintained tuning fork to record continuously the tension in the wire passing through a wire-drawing machine. The principle is the elementary one that, as with a violin string, the tension of the wire determines its natural frequency of oscillation. Yet another new instrument, which has proved consistent and sensitive in preliminary laboratory tests, has been designed to measure small differences of pressure, independently of temperature effects, near the roof of an open-hearth furnace. Although it would clearly be premature to assess the future value to the industry of BISRA's physical department, the new laboratory has got away to a flying start.

Unesco's 8 million dollar Budget

AT the second General Conference of Unesco, held in Mexico City last month, Austria, Hungary, Italy and Switzerland were voted to full membership. Unesco's total budget for 1948 amounts to 8 million dollars, an increase of 2 million over the 1947 figure.

A Russian Atomic Bomb?

LAST month it was reported that the Russians burst their first atomic bomb in June of this year on a testing ground near Irkutsk. The report, which appeared in the Paris paper *L'Intransigeant*, followed closely on Molotov's speech made at the celebrations of the USSR's 30th anniversary in which he said the secret of the atomic bomb "has long ceased to be a secret". In informed circles it has been pointed out that Molotov's remark could equally well have been made in 1945 immediately after the publication of the Smyth report, and there are many atomic experts who are not yet convinced that Russia has succeeded in producing an atomic bomb.

Centenary of Chloroform Anaesthesia

IN November 1847 Sir James Young Simpson, professor of midwifery at Edinburgh University, discovered the anaesthetic property of chloroform. The centenary was celebrated at Edinburgh University last month, lectures about the discovery and the present use of chloroform being delivered by Dr. Douglas Guthrie, Professor R. R. Macintosh, Dr. D. S. Middleton and Dr. John Gillies.

Chemical Society's New Secretary

MR. J. R. Ruck Keene, M.B.E., B.A., has been appointed General Secretary of the Chemical Society in succession of Wing Commander L. R. Batten.

Canada's Second Atomic Pile

FOR slightly over two years a low-power atomic pile using heavy water as moderator has been operating in Canada. Recently, states *Chemistry and Industry*, it was announced that a new heavy water pile on the Chalk River had begun operating. This is described as 'several thousand times' more powerful than the first pile. At present, Chalk River atomic energy establishment of the Canadian Government, which cost 20 million dollars to construct and about 3½ million dollars a year to run, is producing at least fourteen isotopes. Spokesmen of Canada's National Research Council have stated that the atomic developments are behind schedule owing to lack of trained personnel.

Salt on Icy Roads

SALT is commonly used in Britain during snowy weather to prevent roads becoming ice-bound. An alternative to common salt is calcium chloride; down to a temperature of 10° F. common salt is the more effective, but at temperatures in the region of −6° F. it is of little use and is quite ineffective below −8° F., whereas calcium chloride can be used down to about −58° F. As common salt is cheaper than calcium chloride it would normally be used unless the temperatures were so low as to make it inefficient, a condition rarely met in the southern half of Britain. Calcium chloride might be required more frequently in northern districts. Full details about the chemical clearance of snow are to be found in the Road Research Laboratory's publication, *Chemical Treatment of Icy Roads*, published by Stationery Office, Price 3*d*.

U.S. Scientific Office in London

A MISSION on science and technology will be established soon in the U.S. Embassy in London to direct the exchange of scientific information and personnel between the United States and Great Britain. The mission, consisting of a small group of scientists and engineers and headed by Professor Earl A. Evans, jun., will carry out liaison work similar to that done by the British Commonwealth Scientific Office in Washington. The U.S. Government is planning to set up scientific missions in other capitals.

German-Japanese Technical Reports

ALL inquiries regarding German and Japanese reports (which have hitherto been directed to B.I.O.S. at Bryanston Square, W.1), and applications to examine original documents (in the past addressed to Documents Unit, German Division, Board of Trade, Berkeley Square, W.1) are in future to be sent to a newly-formed centralising department—Technical Information and Documents Unit, German Division, Board of Trade, 40 Cadogan Square, London, S.W.1.

Night Sky in January

The Moon.—New moon occurs on Jan. 11d 07h 44m, U.T. and full moon on Jan. 26d 07h 11m. The following conjunctions take place:

January				
8d 14h	Jupiter in conjunction with the moon,		Jupiter 3°	N.
14d 04h	Venus	,,	Venus 4	N.
27d 05h	Saturn	,,	Saturn 4	S.
28d 06h	Mars	,,	Mars 0·6	S.

The Planets.—Mercury is in superior conjunction on Jan. 3 and becomes an evening star, setting at 17h 16m and 18h 15m at the middle and end of the month, respectively. In the last case this is about 1½ hours after sunset, so it is possible to see the planet in the western sky, but it lies rather low for good visibility. Venus, an evening star, sets at 18h 23m, 19h 08m, and 20h, at the beginning, middle, and end of the month, respectively, and is conspicuous in the western sky, shining brightly with stellar magnitude —3·4, more than 80 per cent of the illuminated disc being visible. Mars, in the constellation of Leo, is visible throughout the greater portion of the night, rising at 21h, 20h 04m, and 18h 41m, at the beginning, middle, and end of the month, respectively, and is easily identified from its ruddy hue and brightness (stellar magnitude about 0). Jupiter rises in the morning hours at 6h 20m, 5h 40m, and 4h 50m, at the beginning, middle, and end of the month, respectively. Its stellar magnitude is —1·4 and it may be identified from its azimuth when near the horizon, which is about 50° from the south. As the planet does not rise more than 16½° above the horizon during the month, it will not be very well placed for observation. Saturn rises at 19h 46m, and 17h 30m on Jan. 1 and 31, and is easily recognised in the Constellation of Leo, a little north-west of Regulus, which is about a magnitude fainter than Saturn. The earth makes its closest approach to the Sun —about 91,450,000 miles—on Jan. 2.

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